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THE PARLIAMENT OF THE COMMONWEALTH OF AUSTRALIA.

NINTH ANNUAL REPORT

OF THE

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

FOR

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Commonwealth Scientific and Industrial Research Organization.

NINTH ANNUAL REPORT FOR YEAR 1956-57.

I. INTRODUCTORY.

1. General.

The Commonwealth Scientific and Industrial Research Organization was established in 1949, when the Science and Industry Research Act 1949 was proclaimed. Under that Act the Organization took the place of the existing Council for Scientific and Industrial Research, which in turn in 1926 had taken the place of the former Institute for Science and Industry.

The powers and functions of the Organization include: the initiation and carrying out of research in connexion with, or for the promotion of, primary and secondary industries in the Commonwealth of Australia, or any territory of the Commonwealth of Australia, or in connexion with any matter referred to the Organization by the Minister; the training of research workers; the making of grants in aid of pure scientific research; the testing and standardization of scientific apparatus and instruments, and the carrying out of scientific investigations connected with standardization; the collection and dissemination of information relating to scientific and technical matters; the publication of scientific and technical reports and periodicals; and acting as a means of liaison with other countries in matters of scientific research.

2. Executive.

As from 1st January, 1957, the titles of the following members of the Executive were changed as follows:—

Dr. F. W. G. White—Deputy Chairman.
Dr. S. H. Bastow—Chief Executive Officer.

In March, Dr. H. C. Forster resigned as Assistant Executive Officer to accept appointment as Professor of Agriculture at the University of Melbourne.

3. Secretariat.

As from 1st January, 1957, the titles of the following members of the Secretariat were changed as follows:—

Mr. F. G. Nicholls—Research Secretary (Scientific Services);
Mr. G. B. Gresford—Research Secretary (Physical Sciences);
Mr. W. Ives—Research Secretary (Biological Sciences);
Mr. D. T. C. Gillespie—Assistant Research Secretary (Staff);
Mr. P. F. Butler—Assistant Research Secretary (Biological Sciences).

4. New Division.

The Section of Land Research and Regional Survey, with head-quarters at Canberra, Australian Capital Territory, has been designated a Division, and Mr. C. S. Christian, B.Agr.Sc., M.S., Chief of the Division.

5. Advisory Council.

The following members retired from the Advisory Council during the year:—

Mr. W. A. Gunn, C.M.G.;
The Hon. O. McL. Falkiner, M.L.C.

The following new members have been coopted to the Council:—

Mr. E. P. S. Roberts;
Professor H. C. Forster, M.Agr.Sc., Ph.D.;
Mr. C. M. Williams, O.B.E.

6. Visit of H.R.H. Prince Phillip.

His Royal Highness visited the Canberra Laboratories of the Organization during November, 1956. He inspected displays illustrating the work of the Division of Land Research and Regional Survey and the myxomatosis investigation of the Wildlife Survey Section. He also examined research being undertaken on termites by the Division of Entomology and on plant nutrition by the Division of Plant Industry.

7. Honours and Awards.

Sir Ian Clunies Ross: Gold Medal, Royal Agricultural Society of England; Honorary Degrees of Doctor of Science, Universities of Adelaide and New England; 1957 James Cook Medal of the Royal Society of New South Wales.

Dr. H. R. Marston, Chief, Division of Biochemistry and General Nutrition: Honorary Doctor of Science, Australian National University.

Dr. E. G. Bowen, Chief, Division of Radiophysics: Honorary Doctor of Science, University of Sydney: Fellow of the Australian Academy of Science.

Dr. C. H. B. Priestley, Chief, Division of Meteorological Physics: 1956 David Syme Research Prize of the University of Melbourne.

Mr. F. N. Ratcliffe, Officer-in-charge, Wildlife Survey Section: Order of the British Empire.

Dr. J. Griffiths Davies, Assistant Chief, Division of Plant Industry: 1957 Australian Medal of Agriculture, Australian Institute of Agricultural Science.

Mr. G. B. Gresford, Research Secretary (Physical Sciences): Commonwealth Fund Fellowship.

Dr. A. J. Anderson, Senior Principal Research Officer, Division of Plant Industry: Doctor of Science, University of Western Australia.

Dr. W. J. Scott, Senior Principal Research Officer, Division of Food Preservation and Transport: Degree of Doctor of Science, University of Melbourne.

Dr. J. R. Price, Senior Principal Research Officer, Division of Industrial Chemistry: 1956 H. G. Smith Memorial Medal, Royal Australian Chemical Institute.

Dr. J. M. Cowley, Principal Research Officer, Division of Industrial Chemistry: Doctor of Science, University of Adelaide.

Dr. M. F. Day, Principal Research Officer, Division of Entomology: Fellow of the Australian Academy of Science.

Dr. J. D. Morrison, Principal Research Officer, Division of Industrial Chemistry: Commonwealth Fund Fellowship.

Mr. K. E. Murray, Principal Research Officer, Division of Industrial Chemistry, and Mr. W. G. Crewther, Principal Research Officer, Wool Textile Research Laboratories: 1956 Grimwade Prize (shared), University of Melbourne.

Dr. A. D. Wadsley, Principal Research Officer, Division of Industrial Chemistry: Doctor of Science, University of Tasmania.

Dr. R. F. Williams, Principal Research Officer, Division of Plant Industry: Doctor of Science, University of Adelaide.

Dr. M. E. Winfield, Principal Research Officer, Division of Industrial Chemistry: Doctor of Science, University of Western Australia.

Dr. G. Baker, Senior Research Officer, Mineragraphic Investigations Section: Doctor of Science, University of Melbourne.

Mr. J. A. Macinante, Senior Research Officer, Division of Metrology: 1955 Mechanical Engineering Prize, Institution of Engineers, Australia.

Dr. N. T. M. Yeates, Senior Research Officer, Division of Animal Health and Production: Associate Professorship of Livestock Husbandry, New England University.

8. OVERSEAS VISITORS.

The Executive of C.S.I.R.O. was pleased to have as its guest Dr. M. S. Thacker, the head of its sister organization in India—the C.S.I.R. Dr. Thacker spent a month visiting Australian institutions and establishments of the Organization. During this visit Dr. Thacker attended the U.N.E.S.C.O. Symposium on Arid Zone Climatology.

Every year a number of leading overseas scientists visit various Divisions and Sections, and many actively co-operate on research projects.

Visitors included Dr. M. Davies, University College of Wales, Aberystwyth, at the Division of Electrotechnology, and Mr. A. D. McKay, of the Matropes Research Station, Bulawayo, Southern Rhodesia, at the Division of Plant Industry, under Royal Society and Nuffield Foundation Commonwealth Bursaries.

Dr. H. H. Rabben, of the Fraunhofer Institute, Freiberg, Germany, at the Division of Radiophysics, studying solar radio astronomy techniques.

Dr. P. J. Darlington, Curator of Insects at the Museum of Comparative Zoology, Harvard, at the Division of Entomology studying insect collections held by the Division.

Dr. Merle A. Tuve, Director of the Department of Terrestrial Magnetism, Carnegie Institute, Washington, and Dr. Lloyd V. Berkner, President of Associated Universities Inc., New York, at the symposium on " Radio Astronomy " at the Division of Radiophysics.

Dr. F. K. Harris, of the National Bureau of Standards, U.S.A., at the Division of Electrotechnology studying the measurement of small capacitors.

Professor J. Bonner, Professor of Biology in the California Institute of Technology, Pasadena, at the Division of Plant Industry.

Professor C. E. Zobell, of the Scripps Institution of Oceanography, California, at the Division of Fisheries and Oceanography.

Mr. D. Williams, of the University of Reading, at the Dairy Research Section under a British Memorial Fund Fellowship.

Mr. R. T. Cortes and Mr. J. B. Seguerra, of the Forest Products Laboratory, Laguna, the Philippines, at the Division of Forest Products.

Mr. Meyill, of the U.S. National Bureau of Standards, and Professor Peterson, of Stanford University, at the Radio Research Laboratories to install special equipment at Camden in preparation for the observations during the International Geophysical Year.

In addition a number of scientists from overseas have visited the Organization as delegates to conferences and symposia, and under the Colombo Plan and various training schemes.

9. FUNDS FOR WOOL RESEARCH.

The financing of the Organization's research for the wool industry will in future be on a more satisfactory basis as a result of the Wool Research Act passed by Parliament this year. The development of the programme during recent years has been possible only because of the reserves of money accumulated in earlier years and by the expenditure of capital from the Wool Industry Fund. Under this new Act wool-growers will contribute 2s. per bale annually towards research on wool and the Commonwealth Government will contribute 4s. per bale on all wool produced. At the current level of wool production this should provide about £1,500,000 per annum for wool research. In addition a further sum of approximately £200,000 will be available from interest on the residue of the former Wool Industry Fund. Thus in future the income into the Wool Research Trust Fund may be of the order of £1,700,000, and will be sufficient to cover the present annual expenditure by C.S.I.R.O. and other participants, and to allow some modest expansion of the research programme over the next few years.

The Fund will be administered by a Research Committee including representatives of wool-growers' organizations, textile manufacturers, the universities, the Commonwealth Department of Primary Industry, and the C.S.I.R.O. This Committee will make recommendations for expenditure on research programmes for the approval of the Minister for Primary Industry and the Minister in charge of the C.S.I.R.O.

10. HAFNIUM ZIRCONIUM PATENTS.

For a number of years the Organization has held patents covering an improved process developed in the Division of Industrial Chemistry for the separation of hafnium from zirconium. During the current year the world rights (outside Australia) to manufacture under these patents have been granted to the National Distillers and Chemical Corporation of the United States of America. The Corporation has agreed to initial payments totalling 250,000 dollars (in installments) together with half of all royalty payments received under sublicensing agreements.

This is the highest return so far received by the Organization for any of its patents, and will add substantially to the funds which accrue from other licence agreements contracted with respect to inventions developed by the C.S.I.R.O.

11. GIANT RADIO TELESCOPE.

The design study for the proposed giant radio telescope to be erected for the Division of Radiophysics is nearing completion. When this design study is available it will be reviewed by a scientific committee in Australia, and the final form of the instrument will be decided upon. Available sites for the erection of the telescope are being surveyed.

12. AUSTRALIA'S WATER RESOURCES.

The Organization's two main research projects relating to water supplies which have been reported in previous years have now developed with great promise.

The work of the Division of Radiophysics on artificial rain-making is reported in Chapter XXVII., Section 8. The full-scale field trial over the Snowy Mountains has now been in operation for two winters, and the results to date show promise of an increase in rainfall over the target area. A similar experiment has now been begun in South Australia, but significant results may not be available for several years. At the request of various State Authorities in June, 1957, the Division organized special emergency cloud-seeding operations, in an attempt to induce the maximum possible precipitation of rain from suitable cloud formations over areas which were acutely short of water.

The Mansfield process developed in the Division of Industrial Chemistry (see Chapter XVII., Section 5) is now finding application for the reduction of evaporation from small farm dams, and in modified form has been shown to be effective in large reservoirs.

13. CATTLE FOR NORTHERN AREAS.

The Organization has for many years been studying the problems of the cattle industry in Australia's tropical and semi-tropical areas. The full report of the current year's work is given in Chapter VIII. Two aspects of interest are worthy of special note.

The Cattle Tick Research Review Committee appointed by the Executive in 1956 to review and coordinate cattle tick research in the universities, State Departments of Agriculture, and the C.S.I.R.O. Divisions of Entomology and Animal Health and Production, has now completed its survey and made recommendations to the Executive at the following three levels of urgency:—

(*a*) Completion of the ecological background and field tests of pasture spelling and strategic dipping. Studies of the tick fevers to assess the consequences of efficient control of ticks.

(*b*) Toxicological investigations, with completion of the work on DDT being the most urgent project.

(*c*) The study of tick resistance in cattle.

The investigations of the Division of Animal Health and Production and the Animal Genetics Section to establish the genetic factors which enable cattle to withstand tropical conditions are still being pursued. Contrary to earlier thought it has now been found that the sweating rate of Zebu crossbreds is not necessarily higher than the average of the British breeds. The ability of the Zebu types to withstand heat relates therefore to other factors, and the investigation is being developed on such aspects as coat characteristics.

14. CONFERENCE ON ARID ZONE CLIMATOLOGY.

The Organization cooperated in arranging the Australia-U.N.E.S.C.O. Symposium on Arid Zone Climatology with special reference to microclimatology. The object of this conference was to discuss current research, and to examine its application to the solution of problems of arid and semi-arid areas. It was held at the University College, Canberra, and delegates from twenty countries attended.

15. COLLABORATION WITH THE UNIVERSITIES.

Many of the Divisions and Sections have close ties with the universities and work undertaken in cooperation in this way is described in the appropriate sections of this report. However, a number of new arrangements have been made with the universities during the year, included amongst which are the following:—

Officers of the Animal Genetics Section have over a period of years developed a course of lectures in genetics for students in the Department of Zoology of the University of Sydney. The course of 50 lectures previously arranged for post-graduates has been expanded and taken over by University staff.

The Division of Fisheries organized a School of Marine Biology in June 1957, which was attended by students from the Universities of Sydney and Adelaide.

The Organization is cooperating with the New England University, Armidale, in the establishment of a laboratory to be used jointly by the staff of the Faculty of Rural Science and research staff of the Organization's Regional Pastoral Laboratory, Armidale. The personnel from the two establishments will collaborate freely on research projects, and a joint Research Committee has been established to integrate the work of the Faculty of Rural Science and the Regional Pastoral Laboratory. Officers of the Organization will deliver lectures in the academic work of the Faculty, and assist with post-graduate courses and the supervision of research projects.

The University will grant honorary titles and status to officers of the Organization participating in the teaching work of the Faculty.

The Organization is cooperating with the University of Melbourne in the establishment of a joint Engineering Research Station for the study of soil mechanics. The Organization is sharing with the University the cost of the erection of a building on a site provided by the Victorian Country Roads Board at Syndal. The proposed laboratory will provide accommodation for staff engaged on extension activities of the Civil Engineering Department of the University, together with officers of the Soil Mechanics Section of the Organization's Division of Soils. A substantial portion of the funds for the laboratory will be provided by the Department of the Army, and major projects for investigation will relate to studies of soil stabilization suited to road and airfield construction.

An officer of the Division of Tribophysics, which cooperates closely with many Departments of the University of Melbourne, was seconded to the Department of Chemistry to work on problems of the solid state.

Officers of the Division of Building Research delivered lectures to architecture students of the University of Melbourne.

The University has given financial support to the Mathematical Instruments Section for the construction of a transistor decimal digital differential analyser.

A grant is being made to the University of Sydney for a period of five years for the appointment of a Reader in the Department of Animal Husbandry to undertake dairy cattle research.

A wool scouring plant which had become surplus to the requirements of the Wool Textile Research Laboratories has been made available on extended loan to the Department of Textile Technology at the New South Wales University of Technology.

The following new grants for extra-mural research have been made to the universities during the year: a grant to the University of Melbourne for research on the inhibition of growth of lactic acid in milk; a grant to the University of Sydney for research on artificial insemination; a grant to the Chemistry Department, University of Sydney, for research on the permeability of monolayers of cetyl alcohol; a grant to the Zoology Department, University of Adelaide, for research on liver fluke in snails; a grant to the Department of Organic Chemistry, University of Sydney, for research on wood and bark; a grant to the University of Sydney for the Colloid Science Research Unit; a grant to the University of Queensland for research on protozoology; a grant to the University of Adelaide for research on animal ecology; a grant to the University of Western Australia for research on marsupials. A list of grants to universities under the Wool Industry Fund appears in Chapter XXXV.

16. CO-OPERATIVE RESEARCH WITH INDUSTRY.

The Organization encourages industrial establishments to join with it in co-operative research projects and programmes. Industry can enlist the collaboration of the Organization's research resources in activities ranging from single sponsored research projects to autonomous research associations.

The report of the work of the Industrial Research Liaison Section, established to strengthen the liaison between the Organization and secondary industry, is given in Chapter XXXI., Section 4.

Support for the Australian Leather Research Association and the Bread Research Institute of Australia has continued under financial arrangements whereby the Organization makes a contribution to their running costs. The Wine Research Institute has now completed its third year. During the year progress has been made with the establishment of the Tobacco Research Institute. A research station has been purchased at Mareeba, and a laboratory building is now in course of construction. A Director and research staff have been appointed, and work has commenced on the investigational programme.

The year has seen an addition to the growing list of Research Associations recognized by the Organization. New South Wales colliery proprietors together with colliery owners in Queensland have combined to establish the Australian Coal Association (Research) Limited to conduct research into mining, marketing, and uses of coal and by-products of coal and coal-mining. Member establishments have agreed to subscribe to the expenses of the Association in proportion to the total tonnage of coal produced by their collieries, and the Association has received recognition from the Organization to qualify for a grant from the Commonwealth Government.

During the year negotiations have been effected for a number of new sponsored research projects with industry. These include:

Investigations on the mechanization of cheese manufacture and commercial-scale butter storage for the Australian Dairy Produce Board at the Dairy Research Section; construction of a transistor decimal digital differential analyser for the Snowy Mountains Hydro-electric Authority and the University of Sydney by the Mathematical Instruments Section; research on the flotation of base metal ores for Consolidated Zinc Pty. Ltd. and the gravity concentration of oolitic iron ores for the Broken Hill Pty. Co. Ltd. by the Ore-dressing Laboratory, Melbourne; a three-year programme of research on plywood for the Australian Plywood Board by the Division of Forest Products; pole investigations for the Electricity Supply Association of Australia, the Postmaster-General's Department, and the Forests Commission of Victoria by the Division of Forest Products; research on fundamental aspects of the refining of lead for the Broken Hill Associated Smelters Pty. Ltd. by the Division of Tribophysics.

The firm of Smith, Kline, and French Laboratories of Philadelphia, United States of America, has made a substantial contribution to the support of research in the Division of Industrial Chemistry on the examination of Australian plants as sources of drugs. This firm is also collaborating with the Division by carrying out systematic pharmacological screening of extracts from Australian and New Guinea plants.

C.S.R. Chemical Pty. Ltd. has supported the Division of Physics on the diffusion of light by scattering media.

The above co-operative research projects are additional to those noted in previous Annual Reports. A full list of contributions and donations for research received by the Organization is given in Chapter XXXV., Section 2.

17. Buildings and Accommodation.

During the year the following buildings were completed:—

New South Wales—
  Prospect—Animal House No. 1, Division of Animal Health and Production.
  Sydney—Ian McMaster Wing, Division of Animal Health and Production.

Victoria—
  Aspendale—Main Laboratory and Wind Tunnel, Division of Meteorological Physics.

Australian Capital Territory—
  Canberra—Air-conditioned insectary, Division of Entomology.

Tasmania—
  Hobart—Annexe at "Stowell", Division of Food Preservation and Transport.

The following projects are in course of construction:—

New South Wales—
  Prospect—Main Laboratory, Division of Animal Health and Production.
  Ryde—Library extension, Wool Textile Research Laboratories.

Victoria—
  Highett—Workshop, Engineering Section.
  Geelong—Extension to weaving shed, Wool Textile Research Laboratories.

Australian Capital Territory—
  Canberra—
    Genetics and Microbiology Laboratories, Division of Plant Industry.
    Service Building, Division of Land Research and Regional Survey.

South Australia—
  Adelaide—Main Laboratory (first stage), Division of Soils.

Queensland—
  St. Lucia—Plant and Soils Laboratory.
  Mareeba—Laboratory and three staff houses, Tobacco Research Institute.

18. Overseas Visits, Fellowships, and Studentships.

Officers of the Organization represented Australia at a number of important overseas scientific conferences during the year. These included the Second International Conference on Surface Activity, London; International Dairy Congress, Rome; International Committee on Weights and Measures, Paris; World Power Congress, Vienna; and the World Eucalyptus Conference, Rome.

Six officers went overseas for short periods as advisers on F.A.O. assignments, at the invitation of U.N.E.S.C.O., under the Colombo Plan, or at the invitation of overseas governments.

During the year a number of officers were sent overseas for periods from two to twelve months to collect information on new developments in scientific research and to acquire general experience in their particular fields. In addition, three officers went overseas at the invitation of overseas universities and other research organizations for consultations concerning special aspects of their work.

Seven Australian graduates were given awards to enable them to undertake advanced research training overseas, and in addition, five officers were awarded overseas studentships for the same purpose. A further four officers were awarded Divisional Studentships for study in the United Kingdom.

In addition to these awards for study overseas, 40 senior Australian students were awarded studentships to continue their post-graduate studies towards higher degrees at Australian universities. Four Divisional Studentships were also awarded to officers for study in Australia, and four English graduates were awarded post-graduate Australian studentships.

The Organization continued to provide training facilities for students and Fellows coming to Australia under the auspices of the Colombo Plan, F.A.O., and U.N.E.S.C.O.

19. Science and Industry Endowment Fund.

During the year the Executive, as Trustees of the Science and Industry Endowment Fund, awarded grants to assist research workers as follows:—Mr. Tarlton Rayment, to complete a catalogue of the *Apoidea* of Western Australia and for studies on the morphology and pollination of heaths; Dr. D. J. Pearson for work on Australian marsupials; Mr. A. W. Parrott to continue his studies on the taxonomy of Australia wasps; Mrs. P. Mather to complete her studies on the ascidian fauna of Australia; Mr. W. H. Dawkin to complete historical and biological studies on whale populations; Dr. Mary E. Gillham, for studies on the ecology of the mutton bird nesting areas in Bass Strait; Mr. C. F. Laseron, for work on Australian Mollusca; Mr. N. V. Dobrotworsky, for work on the ecology and taxonomy of mosquitoes.

In addition to the above research grants, small sums were contributed towards travelling expenses as follows:—Mr. H. N. England, Principal Irrigation Officer of the New South Wales Water Conservation and Irrigation Commission, to visit Holland during the course of an overseas visit; Dr. P. J. Claringbold, Senior Lecturer of the Department of Veterinary Physiology, University of Sydney, to attend a conference of the International Biometric Society, Stockholm; Mr. G. R. Meyer, Lecturer of the Department of Zoology, University of Sydney, to study improved methods of teaching biology; senior students of the Zoology Department, University of Adelaide, to visit the Division of Fisheries and Oceanography, Sydney; senior students of the Agriculture Department, University of Melbourne, to visit the Division of Plant Industry, Canberra.

20. FINANCE.

Chapter XXXV. gives details of the expenditure of £6,575,255 incurred during 1956-57 by the Organization from all funds at its disposal. The major portion of this sum was derived from the Commonwealth Treasury—£4,958,724 was expended in connexion with normal research activities, £109,421 on grants to bodies such as the Commonwealth Agricultural Bureau, and £9,725 on capital works under the control of the Organization. The remainder was expended on investigations financed from contributions, viz.: £935,830 from the Wool Research Trust Account, £122,621 from miscellaneous receipts, and £438,934 from the Specific Research Account (including £220,900 Wool Industry Fund). Certain other expenditure was incurred by the Commonwealth Department of Works on building projects for the Organization from funds controlled by that Department. Transactions for rentals and acquisition of sites and buildings were arranged from funds made available to the Department of the Interior for expenditure on behalf of the Organization.

The Organization is particularly gratified by the way in which various bodies continue to support it, and by the marked interest evinced by certain sections of industry which have provided donations for co-operative research. Among the many contributions received, reference may be made to those of the Commonwealth Bank (through the Rural Credits Development Fund), Australian Meat Board, Australian Dairy Produce Board, Australian Egg Board, the Queensland Meat Industry Board, the New South Wales Department of Agriculture, the New South Wales Water Conservation and Irrigation Commission, the Metropolitan Meat Industry Board of New South Wales, the Ian McMaster Bequest, the Alexander Fraser Memorial Fund, the Burdekin Bequest, the Commonwealth Dried Fruits Control Board, the dried fruits industry, the Australian Institute of Mining and Metallurgy, the State Electricity Commission of Victoria, the Cement and Concrete Association of Australia, the timber industry, the Associated Fibrous Plaster Manufacturers of Australia, the Paint Manufacturers' Association, and the pulp and paper industry.

21. ORGANIZATION.

For the purpose of carrying out its research work the Organization has established a number of Divisions and Sections. The Divisions, of which there are now eighteen, comprise the major establishments, which may be further subdivided into Sections; there are also eighteen independent Sections comprising establishments which have not reached a stage of development, so far as the scope and magnitude of their operations are concerned, to justify their designation as Divisions.

In the present Report an attempt has been made to group the material according to its subject matter rather than according to the Divisions or Sections concerned. Additional chapters and appropriate cross-references have been inserted, however, to permit the work of any particular Division to be reviewed as a whole.

As the Organization's investigations extend on a Commonwealth-wide basis and as many of the investigations which are being conducted—particularly those concerned with problems affecting the agricultural and pastoral industries—necessitate experimental work in the field, a number of branch laboratories and field stations have been established in various parts of Australia.

The Head Office of the Organization is in Melbourne and associated with it are the Organization's Central Library, Agricultural Research Liaison Section, Industrial Research Liaison Section, Films Unit, and Editorial, Publications, and Translation groups. The Organization also maintains Australian Scientific Liaison Offices in London and Washington.

The Divisions which have been established (in order of their formation) are as follows:—

Plant Industry, with head-quarters at Canberra and main laboratories at Canberra and Brisbane, regional laboratories at Perth, Hobart, and Deniliquin, New South Wales, and field stations and experiment farms at Canberra, Australian Capital Territory, Lawes and Applethorpe, Queensland, Trangie, New South Wales, and Kojonup, Western Australia.

Entomology, with head-quarters and main laboratories at Canberra, a smaller laboratory in Sydney, and field stations at Trangie, New South Wales, Rockhampton, Queensland, and Perth.

Animal Health and Production, with head-quarters in Melbourne and main laboratories in Melbourne, Sydney, Prospect, New South Wales, and Brisbane; and field stations at Armidale and Badgery's Creek, New South Wales; Cunnamulla, Amberley, "Belmont", and Rockhampton, Queensland; and Werribee and Tooradin, Victoria.

Biochemistry and General Nutrition, with head-quarters at Adelaide and field stations at O'Halloran Hill, Robe, and Brecon, South Australia.

Soils, with head-quarters and laboratories at Adelaide, and branch laboratories at Perth, Canberra, Brisbane, Melbourne, and Hobart.

Forest Products, Melbourne.

Food Preservation and Transport, with head-quarters and main laboratories at Sydney, branch laboratories in Brisbane and Hobart, and minor laboratories at Gosford, New South Wales.

Fisheries and Oceanography, with head-quarters and main laboratories at Sydney, branch laboratories in Perth, Melbourne, Hobart and Thursday Island.

Metrology, *Physics*, and *Electrotechnology*, comprising together the National Standards Laboratory, Sydney.

Radiophysics, Sydney.

Industrial Chemistry, with head-quarters and main laboratories in Melbourne and branch laboratories in Sydney, Adelaide, and Perth.

Tribophysics, Melbourne.

Building Research, Melbourne.

Mathematical Statistics, Adelaide.

Meteorological Physics, Melbourne.

Land Research and Regional Survey, with head-quarters in Canberra and field stations at Alice Springs, Northern Territory, Katherine, Northern Territory, and in the Kimberley region, Western Australia.

The following are the Sections:—

Irrigation Research Stations, at Merbein, Victoria (Murray Irrigation Areas), and Griffith, New South Wales (Murrumbidgee Irrigation Areas).

Radio Research Laboratories, with head-quarters at Camden, New South Wales, and a laboratory in Sydney.

Plant Fibre, Melbourne.

Ore-dressing Investigations, Melbourne, and Kalgoorlie, Western Australia.

Mineragraphic Investigations, Melbourne.

Dairy Research, Melbourne.

Coal Research, Sydney.

Physical Metallurgy, Melbourne.

Wildlife Survey, with head-quarters in Canberra and field stations at Perth, Albury, New South Wales, and Woodstock, Port Hedland, Western Australia.

Mathematical Instruments, Sydney.

Wool Textile Research Laboratories, with head-quarters in Melbourne and additional units in Sydney and Geelong, Victoria.

Agricultural Research Liaison, Melbourne.

Animal Genetics, Sydney.

Engineering, Melbourne.

Industrial Research Liaison, Melbourne.

In addition, Regional Centres (co-operative research units staffed with officers from the appropriate specialist Divisions to attack the problems of a particular region) have been established as follows:—

Tasmanian Regional Laboratory, Hobart.

Western Australian Regional Laboratory, Perth.

II. SOILS.

1. GENERAL.

A fundamental knowledge of the soil is basic to proper land use. The prosperity of Australia's agricultural and pastoral industries all depend on the maintenance of soil fertility. Soil research is essential therefore to the efficient development and use of land resources, improvement in farming methods, more intense cultivation, and soil conservation.

The Organization's research in this field is undertaken by the Division of Soils with head-quarters at the University of Adelaide. Work on soils with special reference to their behaviour under irrigation is undertaken at the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria, and at the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales (*see* Chapter IV., Sections 2 and 3), and at the Regional Pastoral Laboratory, Deniliquin, New South Wales (*see* Chapter III.).

Division of Soils.—Despite the current difficulty in recruiting research staff, the Division has maintained its previous activities, and a number of special developments have also been initiated.

A small unit has been established at Alice Springs to study arid soils. This work has been done from Adelaide during the past three years, but officers of the Pedology Section have now been transferred to Alice Springs in order that the project may be more readily organized and integrated with other work in this field.

Special effort has been directed to the preparation of a new soils map of Australia to replace the 1943 edition, and field work associated with this has been centred in South Australia, which it is hoped will be covered by the end of 1957. It is aimed to complete the whole project by 1960. The initial classification used has been based on that published in the Manual of Australian Soils which has now been issued as an expanded and improved second edition.

The proposal for extending the work of the Soil Mechanics Section is raising this group and its scope of endeavour to a new level. These arrangements will provide suitable laboratory space and increased staff to enlarge the existing programme to include soil stabilization studies. The officer who will take charge of this research is at present overseas studying work in this field at overseas research centres.

Work has now begun on a new building within the university grounds of the Waite Institute which will become the head-quarters of the Division. A portion of the staff will still remain for a time within the building of the Waite Institute, and grateful acknowledgment is made of the assistance of the University of Adelaide in making available this accommodation.

Three officers of the Division have spent part of the year overseas on study leave, and two officers are abroad on studentships. The Division also undertook field survey work in the State of Brunei, North Borneo, in connexion with plans for agricultural resettlement of native population.

2. SOIL SURVEY AND PEDOLOGY.

(Division of Soils.)

The interest of the Government of the British Protectorate of Brunei, Borneo, in food production and land settlement, conveyed through the Department of External Affairs, led to the soil survey of an area in that territory. Some 30,000 acres near the coast were examined in some detail, and another 20,000 acres were given brief inspection during three months of field work. A report on this work has now been completed. The more common soils are acid yellow earths of low fertility, occurring mainly on steep slopes where erosion is checked naturally by the tropical rain-forest. Large areas of strongly acid deep peat occupy the swamps near the main rivers and the sea. Rather small areas on certain valley floors provide more fertile soils suitable for a variety of crops, but with the exception of several hundred acres these were found to be in permanent use. Responses to phosphorus and potassium fertilizers on the most infertile, sandy soils are anticipated from the results of soil analyses, but the greater part of such soils occupy steep slopes where permanent agriculture without adequate soil conservation measures would entail the risk of soil erosion.

(*a*) *Western Australia.*—The programme of detailed soil surveys of proposed and existing irrigation areas on the Swan Coastal Plain is now complete and 310,000 acres in all have been covered in detail. These reports and soil maps, while giving descriptions of the soils, their distribution, and irrigation potential, also provide most of the data required to complete the study of the pedology of the area in relation to landscape development, which will also make possible the compilation of a revised soil association map covering the coastal plain as a whole.

Work on the soils of the wheat belt has continued, with the emphasis on the principles governing the pattern of distribution on the soils. Approximately 17,000 acres have been surveyed in detail at Mackie's Crossing, near York. The mid Tertiary land surface, which has already been studied at Kauring where it is relatively well preserved, is here extensively dissected and truncated. There are, in addition, a number of younger laterite surfaces related to stages in the post-Tertiary uplift and dissection of the landscape.

At Merredin, a detailed soil survey, which includes Merredin Research Station, has been commenced. The soil pattern is complicated by extensive areas of alluvial soils, and of calcareous wind-borne deposits in many parts of the landscape. The latter are at present under investigation, and are thought to have originated from the salt lakes which are a feature of the area.

(*b*) *South Australia and Northern Territory.*—The survey of the Tatiara district of South Australia represents the latest of a group of reports dealing with a large continuous area of the Coonalpyn Downs and the more fertile soils of the adjacent Tatiara district. The rapid survey completed of County Grey, embracing much of the lower south-east, and exceeding 2,000 square miles in extent, will provide a considerable amount of new information on the distribution, fertility, and use of its soils. A similar survey of a larger area to the north, covering the Counties of Robe and Macdonnell, is in progress and will be completed in the next year.

During the year a soil association survey of the land adjoining Lakes Alexandrina and Albert was completed. This work has laid the basis for the future assessment of the irrigation potential of the lakeside areas up to a general elevation of 50 feet above lake level.

A start has been made on a very detailed soil survey of the Mount Crawford Pine Forest (8,000 acres), where detailed information on soil morphology and distribution is required as a basis for salinity and water-table investigations, for fertility trials with artificial fertilizers, and for sample plot establishment.

As a basis for an extensive programme of soil mechanics investigations on the engineering properties of the soils of the Greater Adelaide and neighbouring area, a pedological soil survey has begun of the site of the town of Elizabeth 15 miles north-east of the city. There are two objectives: firstly, to define the soil types for experimental work, and secondly, to study the soil formations typically occurring on the Adelaide plains.

During the period May to November, 1956, an officer visited the United States of America, Great Britain, and Western Europe on study leave; the principal objects of this trip were soil classification and comparative studies between various soil groups. Two related projects have since been commenced. The first is concerned with a new approach to the classification of soils based entirely on the soil profile, its horizons, and their properties instead of external, environmental factors as in many earlier classifications. The second project is concerned with the production of a new soil map of Australia, essentially a question of soil geography. Field work for this map has commenced in South Australia and will be extended to other States before the end of 1957.

During the winter season last year a reconnaissance of the Alice Springs area was carried out from headquarters with the object of assessing the possibilities for the establishment of regional soil studies in that area. This included the examination of soils on certain aboriginal reserves. The results of both aspects of the work have been so satisfactory that field work has begun with the establishment of a new subregion based on Alice Springs.

(*c*) *South-eastern Region.*—As part of a joint project sponsored by the Agricultural Research Liaison Section, a preliminary assessment of the soils of the Yass Valley, New South Wales, and their relation to landscape has been made, and routine traversing of the area is under way. A soil survey of some 3,000 acres of pine forests near Canberra has been made with the purpose of determining any influence of soils on pine growth. Some investigation of seepage areas has been made. Many of these areas have developed in the Canberra district after the 1956 wet season, and are leading to the death of trees and the loss of production. Some of these areas are salty. It is found that the seepages are determined by buried soil layers of low permeability. A broad appraisal of the soil conditions in the Canberra district is being made.

The reconnaissance map of 3,000 square miles of the south coast region of New South Wales has been completed, and more detailed studies in this district have been made at Nowra. The formation of soils on hill slopes and of soil layers on the river terraces and estuaries has been investigated. This work reveals that the soil pattern is a complex of old and young layers, and that the persistence of the older ones depends on the history of erosion and deposition. The older soils have poor tilth and are less productive than the younger soils.

A soil reconnaissance of some 3,000 square miles of wheat-growing country around Wagga, New South Wales, is partly completed. Detailed soil and landscape studies at selected sites show that the soils are developed on two layers of parna and on two hillwash sheets, and that the differential exposure of these accounts for part of the soil differences. These variables account for differences in parent material and age of the soils; differences in drainage also influence strongly the soil profile characteristics. The array of soils is wide and includes grey and brown soils of heavy texture, red-brown earths, solodic soils, red earths, red and yellow podzolics, and prairie soils.

An area of about 170,000 acres at Lower Murrakool has been surveyed in soil associations with traverses 1 mile apart. Detailed studies of selected traverses indicate drastic past phases of wind erosion and deposition, separated by phases of landscape stability during which soil formation with the leaching of lime occurred. The older layers are more dense and plastic than the younger, and differential permeabilities may have practical consequences during irrigation and in any drainage requirements.

(*d*) *Queensland Region.*—Studies of the Darling Downs soils have been brought to completion with X-ray diffraction studies of a range of the red and black basaltic soils by the Clay Mineralogy Section. The Gabbinbar soils, considered the oldest and most strongly weathered of the red soils of the plateau, have not weathered beyond the stage of kaolin dominance in their clay fraction. In this respect they and the more strongly weathered red soils are comparable with the low humic latosols of Hawaii. The younger red soils are kaolin dominant in their surface horizons and grade to montmorillonite dominance in their subsoils and weathered parent materials.

During the year an extensive soil reconnaissance was made in north Queensland, primarily to provide material for use in a study in progress in the south-east region of the phosphorus content of Australian soils in relation to mineral weathering and soil development. Detailed morphological studies were made and samples taken of soils formed from granitic rocks in environments ranging from high to low leaching intensities. A feature of interest is the great depth of the normal red (krasnozemic) soils developed from these rocks under rain-forest in the high-rainfall areas. Many such soils on moderately sloping crests of narrow ridges are 12-15 feet deep, and some exceeded 20 feet and are underlain by many feet of loose grit of decomposed granitic rock.

The extension of the reconnaissance southward from Townsville provided further evidence of the wide spread of soils with solonetzic and solodic morphology associated with a range of parent rocks in subcoastal Queensland. Further occurrences of strongly acid clays underlying neutral to alkaline clay soils, recently found to be widespread in eastern subtropical areas, were recorded.

A detailed soil survey of the Division of Plant Industry's Beerwah experimental area in the coastal lowlands was completed, while a detailed survey of the newly acquired farm of the Tobacco Research Institute, Mareeba, is now in progress.

South-east of Brisbane, some preliminary traverses have been run in preparation for a study of the soils of the Beenleigh area which is an important source of food supply for the city. Development is now extending into poorer soils of which more should be known.

(*e*) *Tasmanian Region.*—Two more sheets in the series "Reconnaissance Soil Map of Tasmania" have been issued. Early work on the Brighton sheet (420 square miles) has been completely revised to conform with the classification system adopted for neighbouring sheets. This reconnaissance mapping, apart from the value of the soil maps to the various authorities concerned with land use, is providing as it progresses background for fundamental studies of soil formation. Suites of soils formed under different environmental conditions from a common parent material may be studied both in the field and in the laboratory. For instance dolerite under different conditions gives rise to black earths, brown earths, grey-brown podzolic soils, and krasnozems. There is some variation in the dolerite both in regard to composition and to properties such as grain size and jointing, and it is not yet known how much, if any, of the variation in the soils may be attributable to these relatively small differences in parent material.

Smaller units of reconnaissance survey have been studied during the year in two northern coastal areas at the request of land use authorities, and the soils of a high-rainfall area in the north-east have been examined. A study has also been made of the wind-blown sands which are a common feature of the eastern banks of Tasmanian river systems.

(*f*) *Soil Microscopy.*—As an aid to interpretation of the morphology of soil profiles and pedogenic processes, investigations based on techniques of soil microscopy have proceeded for several years at the South-eastern Regional Centre at Canberra. This work is in the developmental stage still, but as a result of the researches and the observations of an officer travelling overseas in 1956, it is felt that the approach is better defined and its usefulness established. The studies relate to the soil fabric and constitution of the soil aggregates and to mineralogy of the sand fractions.

During the past year investigations have been concentrated particularly on the morphology and interpretation of clay skins found on surfaces of natural aggregate. To follow this up, a method has been devised for taking undisturbed soil monoliths, and by use of such, a study of the various soil layers of different ages from the south coast, Southern Tablelands, and Riverine Plain of New South Wales has been commenced.

The mineralogy of the coarser fractions of some Tasmanian dolerite soils has been worked on to determine the relationship of large amounts of fine sand in the A horizon. Similarly, samples of laterite from Western Australia have been examined to supply information on the parent material of laterite horizons.

(*g*) *Mechanical Auger.*—During the year a mechanical auger mounted on a Landrover with power offtake has proved successful in taking 2-in. undisturbed soil cores to a depth of 6 feet using a specially designed cutting tube. It may be operated with speed and economy over a wide range of soil moisture.

3. SOIL CHEMISTRY.

(Division of Soils.)

(*a*) *Head-quarters — Adelaide.* (i) *Geochemistry* —The geochemical studies of the basaltic soils and some podzolized aeolian sands of the Mount Burr forest area in south-eastern South Australia have been completed. The redistribution of eighteen elements under the influence of the processes of weathering and soil formation has been studied and where possible has been related to the mineralogical changes which have taken place. The main factors operative in influencing the geochemical distribution of elements in these profiles were the translocation of elements by plant growth, associations with the clay fraction, restricted drainage, and their relative mobility on weathering.

Some aspects of the nutrition of the pine tree forest were considered with respect to the profile studied. Except for zinc, no relationship between the trace element content of the pine needles, pine health, and soil could be found.

As a new project a start has been made on the study of the geochemistry of the three main groups of soils (podzolic soils, brown soils, and krasnozems) developed on dolerite in Tasmania. Fourteen soil profiles with the associated dolerite parent stock have been sampled following a preliminary field survey on the development and occurrence of these soils.

(ii) *Salt Profiles in Soils.*—An exploratory investigation has been carried out on the use of salt profiles to characterize soils in saline areas. A small area of Riverina clay was sampled in an experiment designed to examine the variations in composition of soluble salts with respect to cations—(1) laterally from spot to spot, (2) vertically down the profile, and (3) from time to time through the seasonal cycle. This revealed that salt profiles showed too much variability to be a satisfactory means of characterizing the soil. Much of the variability appeared to be associated with changes over distances of only a few feet. Variations with time were relatively unimportant.

(iii) *Atmospheric Chemistry.*—The sampling and analysis of rainwaters carried out in collaboration with the Soil Conservation Authority of Victoria has been concluded. In a transect running inland from the coast it was found that the influence of oceanic salts on the quantity and composition of the inorganic salts in the rain was not great at places more than 40 miles from the sea.

Very clear seasonal changes in the nature of the inorganic salts in the cumulative weekly samples of rain from Mount Burr Forest in South Australia have become apparent.

Atmospheric studies are to be extended to coincide with other investigations for the International Geophysical Year. Equipment has been assembled and techniques developed to collect samples of air at Alice Springs and near Adelaide, on regular world sampling days, for carbon dioxide determinations. Regular rainfall sampling will also be extended to Alice Springs.

(iv) *Ion Exchange in Soils.*—There is no satisfactory way of measuring absolute values for cation and anion exchange capacities of colloids, such as those of soils, which carry both positive and negative charges. The customary practice of alcohol washing to remove excess salt at equilibrium is open to serious objections. There is need for a generally acceptable method to measure some of these exchange properties of soils. To meet this a technique has been developed to measure the net negative charge and the increase in this charge with pH. The equilibrating electrolyte used is 0.2N ammonium chloride, and this also enables the individual exchangeable cations in the system to be simultaneously determined. The technique can be adapted to equilibration with other concentrations and salts of ammonium or with solutions of primary amine salts.

(v) *Spectrochemical Investigations.*—The method of spectrographic analysis used in these laboratories differs radically in several important features from similar methods developed elsewhere for determining the concentrations of trace elements in soils and related materials. The selected procedure avoids some of the main drawbacks of the other methods.

The main advantages of the method lie in the manner in which the relation between line intensity and concentration is obtained. The occurrence and general magnitude of two sources of systematic error—self-absorption of the spectral line used for analytical purposes and the existence of an interfering spectral line—became clearly apparent and indicated the possible need for certain corrective procedures.

One weakness that the method has in common with other spectrographic methods for similar analyses is that a considerable amount of simple but tedious calculation is required for the expression of the results. At present this can be reduced only with an unacceptable loss of precision. An attempt is being made to reduce or to mechanize these calculations without reducing the accuracy of the analytical results. The technique as developed has now been written up in considerable detail in a form suitable for publication, together with information on the necessary precautions to be observed to maintain suitable precision on different types of samples.

Two large groups of soils are at present being examined by the spectrographic technique, particularly for their trace element status. One group consists of nineteen profiles of terra rossa and rendzina soils from South Australia; the other group includes 28 profiles of many different soil types, together with a large number of surface soils, taken as part of a fertility survey of Queensland soils.

(vi) *Fertility Investigations.*—Some aspects of potassium deficiency in Tasmanian soils are being examined by means of pot experiments, in order to relate the uptake of potassium to the level of exchangeable potassium in the soils and to measure the response to applied potassium at different levels of natural soil potassium. Results will be compared with two South Australian soils of vastly different potassium status. Other aspects of availability and release of potassium from clay minerals are being studied in association with the Clay Mineralogy Section.

Work is being continued, on material made available from a field experiment of the Waite Institute, to assess the residual value of superphosphate on a red-brown earth. From yield data and crop analysis a complete record has been obtained, year by year, of the removal of phosphate from a wheat-barley-fallow rotation. The area chosen had received 24½ cwt. of superphosphate in the twenty years preceding the start of this experiment. Since its inception some of the control plots have been depleted by as much as 112 lb. phosphorus pentoxide per acre, while other plots receiving superphosphate equivalent to 11 lb. and 22 lb. phosphorus pentoxide per acre show further accumulations in the soil. During the currency of the experiment the proportion of phosphorus pentoxide in the dry matter of the crops has steadily fallen. The balance-sheet for nitrogen in this soil is also being examined.

Soils of the Seddon series of Kangaroo Island are noted for their extremely low phosphorus status. Although they respond markedly to applications of superphosphate, the applied phosphate is strongly retained by the soil and seldom is more than 10-18 per cent. of it taken up by the crop. Pot experiments during the year have been directed to studying the dependence of availability on the degree of saturation of the soil with phosphate and the rapidity with which water-soluble phosphate is sorbed and fixed by the soil. Pilot experiments have been carried out to study possible mechanisms for the release of this sorbed or fixed phosphate.

(vii) *Analytical Techniques.*—Flame excitation is now an important technique in simplifying and speeding up many soil analyses. The experience accumulated by the Division over the last few years has been brought together for publication. Principles of flame excitation, isolation, and detection of the radiation, and instrument design have been considered. Particular attention has been given to those interferences likely to affect the determination of calcium, magnesium, sodium, and potassium in soils and plant extracts, the precautions to be taken, and the precision attainable.

(viii) *Miscellaneous.*—Descriptive chemical analyses of type profiles have been carried out as usual for the Pedology and Soil Survey Section. Various specialized analyses have also been made for other Sections, particularly Clay Mineralogy, while spectrographic analyses have been carried out to assist other departments and organizations. The latter work has included analyses of several samples of gidgea leaves in connexion with stock poisoning, investigation of various legumes as possible indicator plants in geochemical prospecting, and numerous other plants for suspected mineral deficiencies.

Salt and moisture studies of the soils at Mount Crawford showed in some soils only slight seasonal changes in moisture. Miscellaneous water samples from bores from some of the native reserves in central Australia have been examined for fluorine and boron; rather high values for boron were sometimes found.

(*b*) *Queensland Region—Brisbane.*—Interest in the chemistry of soil organic matter is now being investigated from two aspects. Research into its translocation in podzols has continued with a detailed study of the influence of the rate of pH and metal ion to organic matter on the mutual flocculation of iron and aluminium with humus preparations. In a second project methods for the dispersion of soil organic matter have also been studied.

During the year a further pot experiment was conducted to study the decrease in manganese uptake by oats resulting from the application of copper and zinc. Under the conditions of this experiment no such decrease was observed, and no indication was obtained as to whether the interaction occurs in the plant, at the root surface, or in the soil. The evidence from past experiments appeared to favour one of the latter two alternatives. Pot experiments carried out to study the value of ethylenediaminetetraacetic acid (E.D.T.A.) as a soil additive to assist uptake of micronutrient metals have shown increased uptakes of copper, iron, and, in some instances, manganese with oats growing on a neutral fen soil. No increase in uptake of these metals occurred if the soil was limed to pH 8.3 before application of E.D.T.A.

Analyses of soil samples for soil survey and pedological studies in this region have continued to occupy much of the time of the Chemistry Section. The determination of total phosphate in soils has been modified because of low recovery of phosphate by the 4-hr. extraction with boiling hydrochloric acid. Ignition of samples with magnesium acetate at 550° C. before extraction with hydrochloric acid gives values for total phosphate in good agreement with those found by fusion analysis.

Typical soils from south-eastern Queensland are being examined for phosphorus and potassium.

(*c*) *South-east Region—Canberra.*—Attention has been directed to the study of phosphorus in the soil with particular emphasis on compounds with iron and aluminium. For the determination of iron-bound phosphate, modifications have been introduced into the dithionite method to ensure complete reduction of the iron, complete recovery of added phosphate, and minimal attack of apatite. It is proposed to use the method to follow the weathering sequence of apatite in soil profiles.

In order to study phosphorus losses by leaching in relation to climate, phosphorus determinations have been made on several profiles from New South Wales. When other analyses are completed, the degree of correlation between phosphorus losses and the present climate will be established. Phosphate soluble in calcium chloride shows seasonal variation in a number of soils.

Further work has been done on the conditions for the formation of crystalline iron and aluminium phosphates. Although such crystalline precipitates can be readily prepared at high temperatures, their rate of formation in the cold is so slow that they must be considered of little importance in the reactions of fertilizer phosphate with soil.

(*d*) *Tasmanian Region—Hobart.*—A considerable amount of work has been done on the potassium and nitrogen status of the soils at Frodsley, in conjunction with other investigations in progress there. Although Frodsley sandy loam is fairly narrowly defined on morphological grounds, it shows a wide variation in the amounts of potassium present. It would appear that this soil is low in any easily mobilizable reserves of potassium, which confirms the low potassium status of the soils at Frodsley. Other aspects of the influence of potassium status of this soil on the potassium uptake by plants and the response to applied potassium are being examined at head-quarters in Adelaide.

Incubation and perfusion investigations on samples of Frodsley sandy loam collected in the spring and again in the autumn have shown that this soil contains normal reserves of easily available nitrogen. Except under very wet and cold conditions, when nitrates would be easily lost by leaching, there is no reason to suspect that lack of readily available nitrogen is a serious cause of poor stock health. The nitrogen reserves in the soil are not correlated with potassium status.

(*e*) *Western Australian Region—Perth.*—Routine chemical work on about 40 profiles has been carried out during the year on samples from surveys at Merredin, York, Bridgetown-Manjimup, and Busselton. The pedology and chemistry of many Western Australian coastal plain soils were covered by a divisional report of the Capel-Boyanup area, and a report of the chemistry of a rather similar sequence of coastal plain soils from the Pinjarra-Waroona area.

A report has also been prepared on the chemical characteristics of fourteen typical profiles of soils derived from lateritic formations in Western Australia. Further chemical work is being carried out to complete the fertility aspects of this study and to seek a correlation with known field responses.

The ironstone gravels associated with different land surfaces in the Northam area are being further studied. Field observations to date enable reasonable hypotheses concerning the genesis of most of these lateritic soil types to be made, and it is thought that the mineralogical and chemical examination of pisolites in these soils will give information regarding—

(i) the effect of soil conditions (i.e. drainage, topography, dissection, age) on the nature of pisolitic gravels and their breakdown and reformed products;

(ii) the pedological influence of hydrous oxides of iron and aluminium in the protection of minerals and the concentration of nutrients; and

(iii) the influence of parent material on the nature of pisolitic gravels and associated soils.

4. Soil Physics.

(Division of Soils.)

(*a*) *Head-quarters—Adelaide.* (i) *Permeability and Pore Size.*—An equation has been derived for the relation between permeability and the size distribution of the pores in isotropic porous material. It has been tested on published data for various sands and porous stones, and good agreement was found between calculated values of permeability and those obtained by direct measurement with water or air as the fluid. It is expected that the equation will find application in many fields concerned with porous materials. Its application to soils is now being studied.

(ii) *Permeability of Soils to Water.*—Laboratory measurements of soil-water permeability under steady-state flow conditions have been continued, and values of permeability for soil water contents ranging from saturation to permanent wilting percentage are being determined.

(iii) *The Neutron Scattering Method of Measuring Soil Water Content.*—A portable neutron meter has been designed and built to specifications of the Division of Soils. Several of these machines have been used in the field during the past year, for the purpose of checking their reliability, and they have behaved satisfactorily.

(iv) *Evaporation from a Bare Fallow Soil.*—The soil moisture profile of a red-brown earth soil, whose surface was bare fallowed, was determined at approximately weekly intervals during the summer and autumn period January-May. These measurements showed that at depths from 30 to 270 cm. below the surface, the soil water content did not change (within a 2 per cent. error of measurement). There appeared to have been negligible evaporation from the soil beneath the dry surface zone.

(v) *Evaporation from the Land Surface in the Upper South-east, South Australia.*—Measurements of the soil water content profile at sites in a lucerne paddock and in the adjacent virgin mallee heath country with similar soil profile on a property near Meningie, have been continued at monthly intervals during the year. Evaporation from the land surface has been computed from the difference between the measured rainfall and changes in soil storage. It appears that evaporation from the lucerne paddock and from the mallee heath is the same to within about 5 per cent. The evaporation rate increased from about 1 mm./day during July-August to a maximum of about 7 mm./day towards the end of October, after which time there was a spectacular drop in evaporation rate corresponding to depletion of soil moisture reserves. Measurements of the water content profile are being made to a depth of 600 cm. using the neutron moisture meter.

Another feature of this project is an attempt, in cooperation with the South Australian Department of Mines, to find out the origin of the ground-water which occurs in this country at depths from 30 to 60 feet below the surface. This work is continuing.

(vi) *Land Drainage and Saturated Permeability of Soils.*—The Lower Murray River swamps which were inundated in the 1956 floods are now in process of reclamation. Equipment has now been made ready to measure in the field the saturated permeability of the soils as one aspect of a project on land drainage requirements and drainage design. This is to be carried out in conjunction with proposed experimental work by the South Australian Department of Agriculture on land until recently flooded.

(vii) *Use of Gypsum in Irrigation Water.*—The establishment of pastures on Riverina clay and similar soils has proved difficult because the surface soil when irrigated deflocculates. The surface soil when wet has poor aeration conditions for germination and if dry a hard crust is formed. In earlier permeability and infiltration studies it has been shown that deflocculation can be avoided if the percolating solution contains sufficient electrolyte. Following this work an establishment trial has been carried out in conjunction with officers of the C.S.I.R.O. Regional Pastoral Laboratory, Deniliquin, New South Wales. In this trial the establishment of subterranean clover, using normal irrigation water and irrigation water to which gypsum (10 m.-equiv./1.) has been added, has been investigated. Preliminary results show that the gypsum treatments gave a mean seedling emergence of 21 per cent., whereas the highest emergence on the untreated plots was 5 per cent. Marked physical differences in the structure of the soil at the immediate surface results from the gypsum treatment.

(viii) *Soil Tillage.*—A field experiment using three types of plough-disk, mouldboard, and chisel—at three depths of ploughing, on a soil that has been reconditioned by three years under pasture at the Waite Institute, Adelaide, has shown that field infiltration and porosity is better maintained where the soil has been ploughed to below the old cultivation depth and the furrow slice inverted. Soil material from below the old cultivated layer was not so readily dispersed by winter rains as the surface soil when brought to the surface by the disk or mouldboard plough.

(ix) *Effect of Shearing and Compressive Forces on Soil Aggregation.*—The deterioration in soil structure after long periods of cultivation is thought to be determined to a large extent by the ability of the soil aggregates to withstand the mechanical forces exerted on them by cultivating implements. These forces may be resolved into normal compression and shearing forces. A simple ring-shear machine, manually operated, has been built, which allows forces which might be encountered in the field to be applied to beds of soil aggregates, and which measures the change in shearing strength as the aggregates are broken down. The extent of aggregate disruption caused by this laboratory "tillage" is determined by measuring the amount which the treated soil disperses in water compared to the "untilled" soil. A loam soil from a red-brown earth under a pressure of 15 lb./sq. in. developed a shear strength of 13 lb./sq. in. when sheared through 90°, and was 90 per cent. disrupted. On the other hand, soil from a krasnozem under the same treatment developed a shear strength of only 10 lb./sq. in. and was only 25 per cent. disrupted.

(x) *Soil Tillage and Microbial Activity.*—As about 50 per cent. of the porosity of soil is made up of pores of less diameter than the size of soil bacteria, organic matter contained in these pores might be considered inaccessible to soil microorganisms. Owing to the theoretical and practical importance of humus accumulation and decomposition, an investigation was made in conjunction with the Soil Microbiology Section to test the above hypothesis. It was found that when soil aggregates were " tilled " in the ring-shear machine in the laboratory there was an increase in microbial activity, as measured by oxygen consumption, which was related to the amount of aggregate disruption caused by the tillage treatment. Although the actual increase was greatest for virgin soils high in organic matter, the relative increase was greatest in soil in which fertility had been depleted by excessive cultivation.

(xi) *Miscellaneous.*—Service work involving physical measurements is done at Adelaide, in the regions in conjunction with soil surveys, and in response to requests from other organizations. On behalf of the C.S.I.R.O. Engineering Section a full year's test has been made of a solar water heater in the Adelaide climate. Information has been supplied to the Electricity Trust of South Australia on soil temperature and thermal conductivity at various sites, in connexion with the design of underground power cables. At the request of the Department of Lands, South Australia, soil drainage conditions at the irrigation settlements at Loxton and Lyrup have been examined.

(*b*) *Queensland Region — Brisbane.* (i) *Structure Alteration in Cultivated Soils.*—The cultivation experiment on the Darling Downs reported last year has been further developed. It is designed to assess the effect of different depths of chisel ploughing upon soil properties and crop yields. The soil used, Mywybilla clay, is a poorly constructed soil upon which germination difficulties and poor crop yields are commonly experienced, in contrast to the better-class black earths occurring in the same locality. Deep cultivation is being tried as a means of producing a better surface tilth and improving germination.

Unfortunately unseasonable conditions have seriously interfered with the programme of planting and harvesting, and only limited information is so far available. It does appear that despite a summer fallow period water is possibly one of the limiting factors in determining yield. This is mainly due to the low permeability of these soils causing limited penetration of rain. In this respect, also, deep ripping is being examined as a factor in improving the penetration and subsequent retention of water by these soils. It has been noted that the depth of drying of the surface mulch by evaporation closely parallels the depth of cultivation. Since an adequate planting rain during the dry autumn is often a control on the agriculture of this area, in dry years deep working may be detrimental in delaying or at times preventing planting, as in this case much heavier falls are required to rewet the evaporated zone.

(ii) *Range of Available Water in Soils.*—It has recently been suggested that precipitation of free ferric oxides in soils inhibits the water available for plant growth. This is of consequence in tropical areas where agriculture is often concentrated on latosolic soils of high iron content. It has been observed by several workers that latosolic soils often have a restricted range of available water. The influence of iron on water retention has been measured by comparing retentivity on samples with and without removal of free iron oxides. Preliminary results suggest that the effect is small and that the high clay content usually met in soils of high iron content is chiefly responsible for the limited range of available water.

(iii) *Water Content Changes in Natural Soils.*—Observations have been continued on the joint project with the Ecology Section, Division of Plant Industry, in defining the microclimate of different forest communities, and assessing the hydrological balance in a small watershed. Detailed measurements of the permeability of the soils have been made to indicate the changes occurring with various degrees of removal of the forest cover. In particular, large changes accompany the introduction of grassland, and the reason for the extreme decreases in permeability is being examined.

(*c*) *South-eastern Region—Canberra.* (i) *Effect of Temperature on the Stability of Soil Aggregates in Water.*—Results obtained with a wet-sieving method for measuring stability of aggregates show that stability decreases as the temperature of the water increases. The magnitude of the effect varies considerably in different soils.

(ii) *Field and Laboratory Assessment of Consistence.*—Correlations have been attempted between field descriptions of plasticity and the results of various of the Atterberg tests, but no significant relation was found. It appears that the property being observed by the field worker is not in fact plasticity but puddlability.

5. SOIL MICROBIOLOGY.

(Division of Soils.)

(*a*) *Phosphates and Soil Microorganisms.*—Research has continued along two lines, one dealing with the microbiological assay of available phosphates by a new method, the other with the mechanisms of solubilizing mineral phosphates.

(i) *Availability of Phosphatic Materials.*—Previously two fungi, *Aspergillus niger* and *Curvularia geniculata,* were used to bioassay available phosphates by adding small amounts of phosphatic materials to liquid media in Petri dishes, but this method was not satisfactory for studying the availability of phosphates sorbed on sequioxides and clays. A number of methods were tried, but finally the Warburg respirometer was used.

Sorbed phosphates were added to a microbial medium containing sugar, ammonium nitrate, and the usual mineral salts, but deficient in phosphate. Inoculum of pure or mixed cultures was introduced into the Warburg flask, shaking started, and the oxygen uptake recorded over a period of several days as a measure of available phosphate compared with potassium phosphate standards. Most organisms have no difficulty in obtaining sorbed phosphate when over one-tenth of the surface of the sesquioxide is saturated, but below this figure the supply is suboptimal for some species.

The Warburg respirometer method was also used to study availability of phosphate from organic substances in the hope that this might throw some light on the nature of the resistant phosphorus compounds in soil humus.

In order to promote more rapid solubilization of rock phosphate in the field, a granular fertilizer has been devised consisting of roughly ground rock phosphate, as used for the manufacture of superphosphate, mixed with elementary sulphur, equivalent to that contained in the sulphuric acid used in producing superphosphate, together with small quantities of nitrogenous fertilizer. In the laboratory, sulphur oxidizing bacteria colonized the granules and produced sulphuric acid which partially dissolved the phosphate.

(ii) *Mechanisms of Releasing Phosphates.*—Many more phosphate-solubilizing organisms have now been isolated from soils and the rhizosphere of plants using a medium containing 1.0 per cent. of glucose, 0.01 per cent. of ammonium nitrate, 0.05 per cent. of " Difco " yeast extract, 0.01 per cent. of calcium chloride, 0.006 per cent. of potassium hydrogen phosphate, and 0.25 per cent. of magnesium sulphate, and adjusted to pH 7. X-ray patterns of the precipitated calcium phosphate show that it is finely crystalline apatite. All organisms which dissolve apatite in this medium produce acidic products. Detailed analyses have been made of organic acids produced by two bacteria, two fungi, and an actinomycete all of which readily dissolved apatite. *Escherichia freundii* produced mainly lactic acid which represented 85-100 per cent. of the non-volatile acids, and tests revealed that it alone without the help of the other acids could completely dissolve the apatite present. Hydrogen sulphide was also produced by this organism in amounts sufficient to blacken ferric phosphate by the formation of ferrous sulphide and to liberate phosphoric acid. An unidentified bacterium produced an abundance of citric acid and smaller quantities of gluconic, glycollic, succinic, and oxalic acids. *Penicillium* sp. formed small amounts of succinic, glycollic, and citric acids, but sufficient to solubilize much of the apatite. An active actinomycete yielded large amounts of succinic acid and smaller quantities of glycollic acid. All organisms which dissolve apatite in this medium produce acidic products.

Numerous other organisms produced hydrogen sulphide, and their influence on availability of phosphates from iron phosphates is being investigated.

(*b*) Rhizobium *Studies.*—Particular attention has been paid to the cytology of strains of the pea-vetch cross-inoculation group, *Rhizobium leguminosarum*, which has been compared with *Rh. trifolii* studied previously. Three distinct phases have been observed in most strains, viz. a megaphase of large, stout bacilli, non-motile or sluggishly so, a metriophase of smaller, slender rods, usually actively motile, and a microphase of tiny, coccoid cells either motile or non-motile. In *Rh. leguminosarum*, megaphase is rare and most cultures show metriophase or less often microphase, whereas in *Rh. trifolii* mixtures of phases occur in roughly the same proportions. In *Rh. leguminosarum* sporulation is rarer than in *Rh. trifolii.*

In conjunction with the agronomic trials of grain legumes at the Waite Agricultural Research Institute, Adelaide, about 100 rhizobial strains have been isolated from *Vicia* (13 spp.), *Lathyrus* (9 spp.), *Lens, Cicer,* and *Pisum* and their effectiveness tested in the glass-house on a number of host plants, such as *Vicia faba* var. *minor* (tick bean), *Lathyrus ochrus* (louvana), and *Pisum arvense* (field pea). Most of these strains were made from plants in an area where peas are commonly grown yet respond to artificial inoculation with rhizobia. The strains vary greatly in cultural characters and in effectiveness.

(*c*) *Fractionation of Soil Humus.*—Numerous amino acids occur in acid hydrolysates of soil humus, which suggests that proteins occur there, but no proteins have been separated or detected after exhaustive tests, and it is now believed that the amino acids occur in non-protein complexes probably resembling " browning reaction " products or melanins. Numerous " browning reaction " products have been synthesized as models for comparing with soil humus. Chromatograms of no single browning product exactly resembled those from humus, but mixtures of melanoidins from quinones, phenols, and sugars with casein amino acids gave similar patterns. Also electrophoretograms of humates and of these mixed browning reaction products were comparable.

(*d*) *Rhizosphere Studies.*—These studies aim to obtain more information on the effect of temperature and light upon exudation of substances from roots of several plant species and to find how these influence the numbers and types of microorganisms occurring in the rhizosphere.

(i) *Root Exudates.*—The effects of age of plant and environmental conditions on exudates from tomato and subterranean clover roots were followed. It was found that both plants liberated more amino acids during the first two weeks following germination than during the two-four week period. In all the experiments tomato exuded about four times as much material as clover when expressed on the basis of dry weight of roots.

Light and temperature both markedly influenced the amounts and composition of exudates, high light intensity and high temperature favouring exudation in both tomato and subterranean clover. This indicates the importance of controlled environment in root exudate studies if results from different experiments and laboratories are to be comparable.

(ii) *Numbers of Bacteria.*—Tomato plants were grown in sand at different light intensities and plate count estimates made of the numbers of bacteria on the roots and in the rhizospheres. When the results were expressed on the basis of numbers per single root system the highest counts were obtained at the maximum light intensity, but expression on the basis of dry weight of roots failed to show any significant differences due to light intensity. Counts of the bacteria in the sand surrounding the roots showed greater numbers in the full light treatment.

(iii) *Bacterial Isolates.*—Several hundred bacterial cultures have been isolated from the roots of tomato plants at different ages and under different treatments. It is proposed to use these cultures in testing the selective mechanisms operating in the rhizosphere and also to test the growth promoting properties of root exudates.

(*e*) *The Effect of Tillage on the Oxygen Uptake of Soils.*—In a joint study with the Soil Physics Section it was found that laboratory " tillage " of a wide range of soils consistently stimulated microbial activity for 12-24 hr. The mechanisms responsible for this increase in respiration have been investigated. It is postulated that the exposure to microbial attack of organic matter which occurred in inaccessible sites prior to the disruption of aggregates is responsible for the boost in microbial activity. This thesis is based on the general finding that up to 60 per cent. of the total pore space of soils comprises pores smaller than 0.001 mm. diameter, and organic matter inside such pores would be protected from direct microbial attack. Disruption of these pores occurs with tillage, and the close relationship between disaggregation and increased oxygen uptake supports the above thesis. The roles of changes in aeration, chemical oxidation of organic matter, and the redistribution of microorganisms with tillage were also investigated but found to be of little or no importance. Drying and rewetting after tillage caused a further increase in activity of some soils, but the effect appeared to depend on the soil management prior to sampling rather than on the disaggregation which occurred.

6. CLAY MINERALOGY.

(Division of Soils.)

(*a*) *Structure of Muscovite.*—Clay minerals of different types have a major influence on the properties of soils. They are formed by the weathering of primary minerals, occurring in the rocks or transported material serving as parent material for soils. Studies of these weathering processes should provide a better understanding of the clay minerals themselves; and since many clays in Australian soils are formed from micas the atomic structure of the mica, muscovite, is being investigated as a first step.

This has been known in its general features for some years, but the atomic positions have never been determined precisely. An integrating Weissenberg camera has been used to collect three-dimensional data about two axes, these intensities being measured on a microphotometer.

(*b*) *Differential Thermal Analysis.*—Within the last year a differential thermal apparatus has been installed, and present results are satisfactory and comparable with those from other laboratories. This equipment records the changes in clay minerals due to dehydration and recrystallization on heating. Such data aid X-ray and chemical techniques in identifying and understanding soil clay minerals. Using synthetic mixtures a straight line calibration for the estimation of goethite in clays has been obtained. This calibration has given results in good agreement with those obtained by X-ray and chemical methods in a few samples. It is hoped that the techniques used will be applicable to the estimation of many minerals in the clay fractions of soils.

(*c*) *Quantitative Mineral Analyses.*—Methods applicable to qualitative analysis must be modified when quantitative results are sought. Estimations, with some degree of accuracy, of the amounts of minerals present in a soil clay are desirable in characterizing its nature. A semi-absolute method of quantitative analysis has been developed with a Philips-Norelco diffractometer to measure X-ray intensities.

This method of analysis has been thoroughly tested with quartz, iron oxides, and other non-clay minerals on natural and artificial samples. Accuracies of several per cent. are attainable, and the method is quick and readily adaptable to additional minerals.

(*d*) *Clay Mineralogy of Australian Red-brown Earths.*—X-ray studies to establish the nature and range of the clay minerals in the recognized great soil groups of Australian soils have been proceeding for some years. Red-brown earths were first examined in 1952, and this year the work was reviewed and extended. The dominant clay minerals throughout southern Australia are illite and kaolin with the former representing 40-60 per cent. of the $<2\mu$ fraction. In addition, there is generally some " mixed layer mineral " present. By contrast the minerals present in Queensland red-brown earths are kaolin with some " mixed layer minerals ". Two soils from the Northern Territory contain montmorillonite as a major component. The clays containing montmorillonite have exchange capacities ranging up to 80 m-equiv. per 100 g. while the others vary between 30 and 60. There is evidence that the illite of these soils, in common with that of many other Australian soils, has a lower potassium content and a higher total exchange capacity than many illites from other countries. Parent material is undoubtedly the main factor determining the mineralogy of Australian red-brown earths. Those soils formed on alluvial or loessial deposits or sedimentary rocks have clay fractions which are mixtures of illite and kaolin. The relative proportions of the two minerals are fairly constant, both within profiles and between profiles. Red-brown earths formed on other parent materials, granite, basalt, etc. show quite a different clay mineralogy in that they contain little, if any, illite.

(*e*) *Phosphate Minerals.*—The mineral form in which phosphorus occurs in soils is of considerable interest and investigations have been proceeding for some time on the less available phosphate minerals. Twelve soils have been studied in detail from South Australia, New South Wales, Queensland, Norfolk Island, and the Cook Islands. In all but the Norfolk Island soil, phosphate minerals were identified and all were of the one structure type. In the Australian soils the minerals were of the gorceixite-florencite series (*see* Annual Report of 1955-56). Earlier overseas work on the soils of the Lower Cook Group had failed to identify phosphate minerals, and it was concluded that the phosphorus was present adsorbed on to iron oxides. The present investigation shows that almost all the phosphorus is present as crandallite, the calcium analogue of gorceixite.

(*f*) *Miscellaneous Mineral Analyses.*—During the year mineral analyses were made on clays from soils of central Australia, Swan Coastal Plain, Western Australia, Launceston Basin, Tasmania, Queensland, South Australia, and New South Wales. The Swan Coastal Plain and Launceston Basin soils both have lateritic associations, and their mineralogy is characterized by clay high in kaolin.

Clay mineral analyses of twenty terra rossa and rendzina soils collected from other countries showed that their mineral composition and variability was much the same as the soils of the same groups previously reported from South Australia (*see* 1953/54 Annual Report).

(*g*) *Fluorescent X-ray Spectroscopy.*—During the year some technical improvements were made to the X-ray spectrograph, and the number of elements being analysed has been extended. Replacement of the Geiger counter tube by a scintillation counter, as detector, has speeded up the operation of the instrument and increased its accuracy and sensitivity. Some hundreds of samples comprising soils, plants, and minerals have been analysed for various elements during the year. It is anticipated that the use of this instrument will continue to grow, particularly for those samples or elements for which conventional methods are precluded by various circumstances.

7. SOIL MECHANICS.

(Division of Soils.)

There appears more than ever wide scope for the Soil Mechanics Section in the study of soils in the field and laboratory as shown in the succeeding paragraphs, and as yet little fundamental work has been done anywhere in Australia. The move recently made to include soil stabilization projects has added a large research responsibility. The Section operates from a head-quarters in Melbourne and a branch in Adelaide.

(*a*) *Conference on Foundation Problems.*—In contacts over recent years between the research staff of the Division and workers in architectural, advisory, and constructional branches of the building industry in Adelaide, it became apparent that a better mutual understanding should exist of the knowledge gained and the problems faced by each group. It was felt desirable to gather representatives of all interested bodies into a conference with the following aims:—

(i) to present to the building industry a statement of present technical knowledge and research findings concerning foundation design;
(ii) to receive from the building industry some guidance as to future research requirements for foundations in the Adelaide area; and
(iii) to establish a basis for the proper functioning of advisory or consultative services with adequate provision for liaison with research and practice.

The conference held in November, 1956, was successful and clarified certain issues. A working committee set up at the meeting agreed on the general lines of future investigations which might be carried on jointly by State Authorities and C.S.I.R.O. Division of Soils in a two-year programme.

The Division of Soils appears to be the only available body with knowledge of the different techniques, and it was recommended that an organized group principally of officers seconded from the State service should be assembled to make a full study of the classification and properties of the soils in a Greater Adelaide area extending over a zone peripheral to the main city district. It has not been practicable to organize the group as yet owing to lack of suitable personnel who have proved difficult to find.

(*b*) *Elizabeth Survey.*—As indicated under the Pedology Section a soil survey is proceeding of the 6,500 acres of the site of the township of Elizabeth on the Adelaide plains. The survey is a prelude to engineering tests of consolidation and shear characteristics on the soil types so defined and to the installation of equipment to measure changes in soil water status over the annual cycle and the movements of the soils due to expansion and shrinkage under seasonal conditions. As the soils of Elizabeth are thought to be typical of a considerable area of the Adelaide plains this pilot survey and test should be a basis for much wider extrapolation. The soil tests will run for several annual cycles; the classification and survey are half completed.

(*c*) *Wimmera Region.*—A project to define soil regions in which the same kind of foundation problems may be expected to occur is being attacked as investigations proceed. One such region is the Wimmera in Victoria extending also into South Australia, and building problems are acute. A limited investigation of foundation conditions in the townships of Horsham and Warracknabeal has been made as in each case there is a high incidence of foundation failures. It is hoped to advance this work in the future. Some long-term tests of soil movement are being observed at Longeronong College near Horsham.

(*d*) *King-street Bridge, Melbourne.* — Considerable work has been done during the year in continuation of tests on deep underlying strata on the sites for the proposed bridge across the Yarra River. The investigation made in collaboration with the Country Roads Board has involved boring, sampling, and testing to depths of 170 feet. The formation consists of mixed alluvium and estuarine muds, silts, gravel, and coarse sand—in a typical layered deposit. Below 137 feet there was increasing evidence of a brittle siltstone which became stronger by 160 feet and continuous at 170 feet. Consolidation tests where samples were recoverable were made and data on the nature and properties of the whole profile collated.

(*e*) *Moisture Conditions in Subgrades.*—The Division has had a continuing interest in changes with time of the moisture content of soils under covered areas. Initially it was shown under buildings that progressive drying occurred, and it was thought that this should apply to paved road surfaces. However, in foreign countries the evidence pointed to accumulation of water under roads, so experiments were proposed in association with the State Road Authorities of Australia to investigate the situation. The research involved installation of equipment to record the subgrade moisture status across a paved road and extending to undisturbed soil at the road margin. This would be a variable dependent on time and environment. The process of water movement was also to be studied. Two installations were made, one at Bordertown, South Australia, one at Horsham, Victoria, in soils of known properties, and records are being made periodically to determine the water status and moisture potential governing flow.

At the last conference of Road Authorities in December it was agreed that the Division should extend its observations considerably. So far this has not been practicable in view of staff availability, but it will be done in the coming year.

(*f*) *Equipment and Techniques.*—Sampling technique and design of sampling equipment have been considered. The work in the muds at the King-street Bridge site (*see* (*d*) gave invaluable experience in both aspects. A report summarizing Australian experience is being prepared. A range of newly designed equipment such as a consolidometer for more rapid working has been built. A mechanical auger has been designed and constructed for sampling to 18 feet.

III. PLANTS.

1. General.

Plants, whether in the form of crops or pastures, are the basis of every agricultural industry, and viewed in perspective grass is Australia's most important primary product. The Organization has placed considerable emphasis on investigations of plant problems at the Division of Plant Industry, which has its head-quarters in Canberra and is the Organization's oldest Division. The work of the Division, which has experimental farms and field stations throughout the Commonwealth, is described in this Chapter.

Allied work on mineral nutrition of plants carried out by the Division of Biochemistry and General Nutrition is described in Section 8 of this Chapter.

Work on special local problems of irrigation districts is undertaken by the Irrigation Research Stations at Merbein and Griffith (*see* Chapter IV.).

The Division of Entomology is carrying out work on weed control, insect pests of pastures and crops, and insect vectors of virus diseases (*see* Chapter IX.).

The Division of Land Research and Regional Survey is carrying out broad-scale ecological surveys in the underdeveloped arid and semi-arid regions of the continent to assess their land-use potential and investigate problems of agricultural and pastoral development. The work of these regional surveys is reported in Chapter XI., Section 2, and the Section's investigations on crops, fertilizers, plant diseases, tillage, and native and introduced pastures under dry-land cultivation at the Katherine Research Station, and under irrigation at the Kimberley Research Station, are reported in Chapter XI., Section 3 et seq.

Research on biophysical aspects of plant growth is being undertaken at the Physics Department of the University of Tasmania and is reported in Section 19 of this Chapter.

In Chapter XXVII., Section 5, is recorded the work of the Division of Meteorology on the meteorological aspects of agricultural problems.

The work of the Plant Fibre Section on fodder conservation and agricultural engineering is reported in Sections 20 and 21 of this Chapter.

In Chapter XVI., Section 12, is recorded the work being undertaken by the Wool Textile Research Laboratories on the biological degradation of cellulose.

In Chapter XVII., Section 7 (c), is reported the work of the Division of Industrial Chemistry on alkaloids in Australian plants; in Section 7 (d) the work of this Division on stock poisons in plants injurious to animals; and in Section 7 (c) the Division's basic research on the nature of chemical compounds exuded during growth by the roots of plants.

Division of Plant Industry.—The research programmes of the Division have continued without major modification, with the emphasis remaining on the establishment, utilization, and maintenance of improved pastures.

In the study of pastures for southern Australia an intensive programme of pasture plant breeding has been initiated with the object of producing types which are higher yielding and more suited to a particular environment than those now in common use. In the first instance grasses of importance to the south-eastern wheat belt of New South Wales are being studied. This work is centred on Canberra and Wagga.

An intensive breeding and selection programme is being undertaken at the Plants and Soils Laboratory, Brisbane, to find suitable grazing legumes for cattle pastures in the brigalow and spear grass regions and in the coastal lowlands in Queensland. Improvement programmes based on the introduction of superior species have already given material benefit. In the spear grass region cattle can be marketed one year earlier than is possible from native pastures; in experiments in the coastal-lowlands sheep and cattle can now be wholly maintained on sown pastures with consequent increase in return; and in the brigalow country introduced grass and legume species have given highly promising results.

The year has seen progress in the development of the Tobacco Research Institute. A research station has been purchased at Mareeba, and laboratory buildings are now in course of construction. Staff has been appointed, and work commenced on tobacco culture. In addition to work in progress at Mareeba, investigations are being undertaken at Canberra into the blue mould disease.

Investigations into the possibility of establishing safflower as an oil crop in Australia have been concluded. Varieties giving economic yields of high-quality oil have been developed, and returns per acre have been shown to be equal to those from wheat in areas suited to the crop.

A significant contribution to principles of weed ecology has resulted from work with skeleton-weed in cereal crops. Selective weedicides, applied before sowing wheat or in the early seedling stage of oats, have been used to manipulate the ecological balance in favour of the crop. Marked increases in grain yield have resulted, and these have been shown to be due to an increase in nitrogen available to the crop.

The Chief of the Division visited India at the invitation of U.N.E.S.C.O. to take part in a Symposium on Genetics and Plant Breeding in South-east Asia held in New Delhi. Dr. Frankel also visited research institutions at the invitation of the Council of Scientific and Industrial Research, India.

A symposium, entitled "Water Relations of Plants", was held at Canberra during the year. Officers of the Division contributed to the 1956 A.N.Z.A.A.S meeting and the 7th International Grasslands Congress in New Zealand, the Australia-U.N.E.S.C.O. Symposium on Arid Zone Climatology at Canberra, and the Plant Breeders' Conference at Longeronong Agricultural College, Victoria.

Among the many visitors to the Division during the year have been a number of Colombo Plan and F.A.O. Fellows. Co-operative research programmes with State and Commonwealth Departments, universities, and overseas organizations have continued.

Grateful acknowledgment is made to the Commonwealth Bank of Australia for contribution to the work of the Division from the Rural Development Fund.

2. PLANT INTRODUCTION.

(Division of Plant Industry.)

(*a*) *International Exchange.*—A feature of the year's work has been the development both internationally and within Australia of closer co-operative arrangements for obtaining and testing useful plant introductions.

Seed and plant material was either sent to or received from some 40 different countries. Incoming material included plants collected in Central America, the West Indies, and Iran.

(*b*) *Agronomic Trials.* (i) *South-eastern Australia.*—Special attention has been given to the search for late summer or midwinter producing types to supplement commercial pasture species. Grasses of interest included strains of *Festuca ampla*, a fine-leaf winter-growing species from Portugal, and the summer-growing *Panicum bulbosum* from south-western United States of America. Pasture grasses from the United Kingdom, including the "Tall Evergreen" strain of fescue, the "S24" strain of perennial ryegrass, and some Aberystwyth strains of cocksfoot and timothy, have performed well under row cultivation.

Difficulty in obtaining effective nodulation has led to poor growth in many introduced legumes. This has been particularly so with *Hedysarum coronarium, Lotus corniculatus*, and *L. maroccanus*.

Strains of Russian comfrey imported from England have been grown under quarantine conditions and are now being multiplied in the field prior to general release.

Among the grasses being fully tested under grazing or periodic cutting, special attention has been given to species of the genera *Phalaris, Festuca, Lolium*, and *Bromus*. Comparative studies of the numerous strains of *Phalaris* tuberosa collected in the Mediterranean region have continued. Of the other species of *Phalaris*, strains from Portugal have continued to be outstanding among introductions of *P. coerulescens*, especially in regions of good rainfall. Single plant studies have been initiated with *P. arundinacea* which has shown good drought resistance as well as capacity to withstand flooding. The usefulness of *P. daviesii*, a hybrid susceptible to cold, wet conditions, may be increased by new strains which are now available. *Bromus inermis* has shown its value as an associate species in mixtures with *Phalaris*, while on the other hand the Kentucky 31 strain of tall fescue, unsuccessful in such mixtures, has been highly productive when grown in association with legumes but without a competing grass.

(ii) *Western Australia.*—Recent introductions of species of *Lathyrus* compared favourably with previous material of this genus. Trials of introductions of the genera *Hyparrhenia, Phalaris*, and *Dactylis* for use in coastal and subcoastal areas have continued. Of these *Hyparrhenia hirta* continues to compare favorably with *Phalaris tuberosa* under cutting and grazing. Some strains of cocksfoot from France are of interest because of their rapid early growth. Cutting trials to compare these and other introductions with the established varieties Currie and Neptune have been commenced.

In the dry inland areas work has been concentrated on strains of Wimmera ryegrass and related species and on annual clovers, although many other species have been tested.

The value of other *Trifolium* species to supplement the use of subterranean clover is being investigated. Of these *Trifolium clypeatum, T. spumosum*, and *T. cherlei* compared favourably with subterranean clover in productivity and seed production. No grass species outyielded Wimmera ryegrass. Some species of *Bromus* showed that they may be of value on heavy soils, and some perennial grasses showed good performance in regions generally considered too dry for them.

The relative salt tolerance of several grasses, including a very tolerant species of *Puccinellia* from Turkey, is being studied.

(iii) *Queensland.*—Emphasis of the work in Queensland has been on agronomic testing of species previously showing promise in nursery trials and on extensive testing of grasses and legumes of special importance to the development of improved pastures in southern Queensland. Grazing trials of many introduced grasses have continued at Samford and Lawes. The very dry conditions experienced, especially at Lawes, have provided a critical test of these introductions, and have confirmed the value of some strains of species of *Panicum, Digitaria, Cenchrus*, and *Paspalum* from South Africa and South America. The genera *Desmodium* and *Indigofera* include many of the more promising species of pasture legumes for use in southern Queensland. All available introductions of these genera including many strains recently introduced from the American tropics have been established at Beerwah for comparative evaluation.

Varietal trials of sorghums, millets, grain legumes, soybean, and vegetable oil crops have continued. The "Rio" and "Palmetto" varieties of sesame from the United States, and some dwarf types of castor bean from Hungary, have proved superior to oil seed varieties previously tested.

(*c*) Phalaris *Growth, Flowering, and Dormancy Studies.*—Collections of *Phalaris tuberosa* and other species of *Phalaris* from the Mediterranean region are being examined to relate growth and development under Australian conditions to that of the natural environment and to compare their agronomic and breeding utilization.

Dry conditions have greatly reduced the populations in natural selection plots established beyond the inland limits of normal *Phalaris* cultivation; thus are shown the capacities of different strains to withstand drought. Samples transplanted from these plots to Canberra when compared with previous transplants should elucidate the adaptive significance of various characters.

Preliminary analysis of a clonal transplant trial at Condobolin, Wagga, and Canberra indicates a difference in the order of flowering time of the collections. Physiological interpretation of these differences has been greatly assisted by studies in which the relative importance of winter preconditioning, photoperiod, and spring and summer temperature in determining flowering has been investigated. The introductions examined show differences in the relative importance of these factors, which can in part be related to the environmental conditions of their place of origin. Yield data are also being obtained from this trial.

Trials of more recent collections of *Phalaris* spp. from the Mediterranean region show that there are large differences between lines in habit, density, coarseness of leaves and culms, and in autumn regeneration. Yield data with emphasis on winter production will also be obtained from this trial during the current year.

(*d*) *Plant Geography and Climatology.*—Work has continued on aspects of the world distribution of grasses with relation to climatological and meteorological factors. The significance of incoming and outgoing radiation for plant growth, especially the interaction of radiation with the water vapour content of the atmosphere, is being studied as a basis for mapping of regions in relation to their potentialities for plant growth. The information obtained will allow for the selection of regions most suited for the agronomic testing of introductions from overseas.

3. GENETICS

(Division of Plant Industry.)

(*a*) *Subterranean Clover.*—The research programmes aim at an understanding of the variation of and adaptive significance of characteristics of the species, their inheritance, and the incorporation of desirable attributes into new strains to extend the geographical or agronomic range.

(i) *Subspeciation.*—Analysis of F_1 pollen indicates that subspeciation has occurred independently in different regions. The majority of Australian strains are moderately fertile when hybridized with Tallarook, exceptions being Wenigup-Clare, and Yarloop-Yabba North, which comprise two separate groups.

(ii) *Flowering Time.*—A biometrical analysis of data from parents, F_1, F_2, and F_3 generations from Canberra has shown that this character is strongly inherited with practically no genetic interactions.

(iii) *Seed Dormancy.*—Tests have shown that seed dormancy is a maternal characteristic and that strains from cool and dry locations exhibit a high degree of dormancy. Laboratory tests have been shown to provide an index of germination in soil.

(iv) *Seed Size and Seedling Growth.*—Studies with two seed sizes in seven strains showed that seed size strongly influences plant size, even beyond flowering time. Growth rate is not strictly proportional to seed size, small seeds being more efficient.

(v) *Strain Testing.*—Testing of introductions and selections in sward trials has continued at Canberra. Ten selections are being sown for testing at Canberra, Deniliquin, and Kojonup.

(*b*) Phalaris *Species.*—As part of a programme of plant improvement, flowering date, winter growth, summer dormancy, and the occurrence of autumn flowering are being studied, and considerable differences between collections have been found. Cloned material has been grown in three locations—Canberra, Wagga, and Condobolin. This with other material has yielded information which is being used to investigate the inheritance of agronomic characters, and the use of recombinants in a plant breeding programme.

Crosses between and within various species have been made in order to clarify the cytogenetic history of the genus.

P. tuberosa-minor hybrids (from a range of material) are being made to attempt production of a desirable short-lived perennial.

(*c*) *Lucerne.* (i) *Winter Growth.*—Spaced plants from 10 strains and 44 F_1's varied in the ratio winter/summer growth rate from 0.0 to over 0.4. The Hairy Peruvian strain, and to a less extent Hunter River, Provence, and an Australian selection showed high combining ability for this character. A Canadian creeping-rooted strain showed highest combining ability for summer growth, but was poor for winter growth. In other experiments winter dormancy was broken by either increased temperatures or by supplementing the natural day-length with low-intensity artificial light. These treatments were supplementary without interactions. Results of this work encourage the view that winter productivity can be greatly improved.

(ii) *Development of Creeping-rooted Strains.*—Incorporation of the creeping-rooted characteristic into a non-winter-dormant lucerne is being attempted by backcrossing of F_1's to Hunter River and to creeping-rooted strains.

(iii) *Strain Trial, Deniliquin.*—Fifteen strains have been established at Deniliquin for testing under irrigated and dry-land conditions, with cutting and grazing treatments.

(*d*) *Cytology and Cytogenetics.* (i) Danthonia *spp.*—Fifteen species combinations were sufficiently compatible to hybridize and produce F_1 plants. In a further thirteen species combinations, fertilization occurred but no F_1 plants were obtained.

All hybrids have extremely low fertility, especially in crosses between diploids. Observed chromosomal aberrations account for only a portion of observed sterility.

(ii) Paspalum dilatatum.—Apomixis previously reported has been demonstrated by the presence of a well-developed embryo prior to anther or stigma exertion.

(iii) Themeda australis.—Chromosome races of $2n =$ 20, 30, 40, 50, and 60 have been found, apparently derived from autopolyploidy. Strains with $2n = 20$ characterize the eastern highlands, but western areas have been colonized by types with $2n = 40$. Physiological studies are to be undertaken on some of this material.

(iv) Hordeum bulbosum.—Tetraploid lines of awnless *H. vulgare* have been produced, by colchicine treatment, for crossing with tetraploid *H. bulbosum,* the aim being production of an awnless *H. bulbosum.*

(v) *Maize.*—Using autotetraploids backcross progenies have been obtained to estimate recombination frequencies in one segment in diploid and haploid male gametes and in diploid female gametes of two heterozygotes.

(*e*) *Developmental and Biochemical Genetics of Higher Plants.* (i) Arabidopsts thaliana.—Eleven mutants with low viability have been examined. It has been found that, unlike most of the slow-growing mutants isolated in micro-organisms, the comparable mutants of *Arabidopsis* require diffusible compounds for normal growth. This is caused by the elimination of other types at various stages of development.

An osmotic mutant has been examined closely as it serves as an example of the genetic control of differentiation. The mutation results in a low solute concentration in the cell causing in turn a low osmotic pressure, decreased turgor pressure, poor water intake, low cell expansion, narrow leaves, and short stalks. A consequent pollen-stigma osmotic unbalance leads to an incompatibility mechanism.

(ii) *Factors Affecting Recombination.*—Attempts to influence recombination through chemicals, genetic means, and through grafts are aimed at overcoming the barrier, imposed by linkage, in selection work. In addition such experiments should help to elucidate some aspects of chromosome structure and the nature of the process of recombination.

(*f*) *Radiation Genetics.*—Comparative studies of different mutagenic agents and investigations on mutation breeding methods have been initiated on the following problems.

(i) *Induction of Disease Resistance.*—This work is concerned with blue mould resistance in tobacco (reported elsewhere) and the induction of resistance to root knot nematode in tomatoes.

(ii) *Extension of Nitrogen Fixation in Legumes.*—Mutants will be selected with altered host-symbiont interactions, with the object of extending the range of nodulation and nitrogen fixation.

(*g*) *Agronomy Genetics.* (i) *Vernalization of* Trifolium subterraneum.—The vernalization requirements of 50 strains of subterranean clover are being examined. All strains show some response, but the requirement varies greatly. Further experiments are in progress to determine the role of temperature and photoperiod in partly vernalized plants.

(ii) *Natural Selection with* Medicago tribuloides.—This work involves an assessment of the ecological significance of pod spines in *Medicago tribuloides.* Lines are being developed which are isogenic except for the spiney character in order to provide material for a study in natural selection.

(iii) *Pasture Plant Breeding.*—At least three strains of each of twelve species of grass, and a number of species of *Medicago* and *Trifolium,* are to be tested for use in the wheat belt. Observations will be initially on spaced plants.

4. GENERAL BOTANY.

(Division of Plant Industry.)

(*a*) *Structural Botany.*—Studies on the early ontogenetic development and histogenesis of monocotyledonous flowers have been continued. Examination of floral histogenesis of representative members of the family Gramineae and Cyperaceae has been completed. Work is in progress on two members of the Juncaceae, *Juncus articulatus* and *Luzula campestris.* Material has also been collected for study of the Typhaceae.

(*b*) *Taxonomy and Systematic Botany.*—Work on a Check List of New England Plants and the compilation of an Index to Australian Generic Names are approaching completion. An Index to Australian Specific Names is in the course of preparation.

Besides specimens donated to the Herbarium by overseas institutions, many Australian specimens have been collected. Special attention has been given to the indigenous species of *Nicotiana.* Studies of this genus have shown there are several new species warranting description, one of which appears to be resistant to blue mould.

5. MICROBIOLOGY.

(Division of Plant Industry.)

(*a*) *Phytopathology.*—Research programmes in the field of plant pathology have been concerned with host-pathogen relationships, the effect of environment on disease development, and various aspects of plant viruses.

(i) *Studies on Phytoalexins.*—The post-infectional appearance of an antibiotic substance or substances resulting from the interaction of the host-pathogen combination French bean/*Sclerotinia fructicola* has been shown to be a general phenomenon in plants. The mechanism responsible for this has been inhibited by pretreatment of the pods with high but sublethal temperatures. This inhibition has been shown to be a temporary one. Further physical, chemical, and biological properties of this phytoalexin have been studied.

Studies of the mechanism checking the growth of the pathogen which accounts for local lesions in host tissue have been continued.

(ii) *Brown Rot Studies.*—Latent spore contamination of peach fruits has been established as a factor in the development of brown rot (*S. fructicola*) of stone fruits.

(iii) *Studies on Sporulation of* Peronospora tabacina—*See* Tobacco Investigations, Section 13 (*b*) (iii).

(iv) *The Physiology of Symptom Development in Plants.*—The disease big bud of tomato and tobacco mosaic virus are being examined in a study on the physiology of symptom development in virus diseased plants. To determine qualitative and quantitative differences in growth substances and inhibitors of normal and virus diseased plants, biological assays are being made on ether extracts from these plants. Indoleacetic acid has been consistently present at a higher concentration than any other growth substance in stems and leaves of all infected plants examined irrespective of their age, the length of time for which they have been infected, or the environmental conditions under which the plants are grown.

Organ formation is also being studied in tomato and tobacco with stem segments cultured aseptically on nutritive agar media. This will enable the effects which virus infection produces on the physiology of their hosts to be defined.

(v) *Biosynthesis of Tobacco Mosaic Virus.*—A programme has been initiated to study the biosynthesis of plant proteins. Initial work has been concerned with the incorporation of radioactive amino acids into the protein of tobacco mosaic virus. Emphasis has been placed on obtaining protein synthesis in cell-free rather than *in vivo* systems.

(vi) *Electrophoresis Studies of Plant Viruses.*—Studies of the state of aggregation of tobacco mosaic virus rods and how the aggregation state affects the behaviour of the virus on the filter paper of the continuous electrophoresis apparatus have been continued. It was found that only virus rods of about two times the normal length and less move freely on the filter paper.

Continuous electrophoresis has also resulted in the partial purification of a stone-fruit tree virus as isolated from cucumber.

(*b*) Rhizobium *Investigations.* (i) *Symbiotic Variation in* Trifolium ambiguum *and* Medicago laciniata.—The apparent resistance to nodulation of *T. ambiguum* has been found to be transitory if plants are maintained for long enough periods. This confirms that resistance in this species is an expression of genetic variation of the host with respect to time to nodulation. A crossing programme has been undertaken to ascertain the nature of the inheritance of the unusual symbiotic variation found in this species. In *Medicago laciniata* the effectiveness of symbiosis is profoundly affected by delays in inoculation. A number of single plant progenies have been obtained for further examination of the influence of the host plant on nodulation of this species.

(ii) *Structural Studies of Root Nodules.*—General nodule anatomy for *Lotononis bainsii, Desmodium,* and *Indigophera* species has been studied, and work on several species of *Lotus* has commenced. Ineffectiveness in subterranean clover nodules, due to a mutation in a strain of bacteria, has been found to be caused by bacteria being retained within infection threads in nodules whose central tissue appears to be almost devoid of the characteristic disomatic tissue of effective nodules.

Studies of the structure of root nodules by means of electron microscopy have been recommenced, with special attention being paid to the intimate association between the bacteroids and the host cytoplasm in which they lie.

(iii) *Studies on Bacteroids.*—Techniques have been developed for the study of the constitution and of physiological functioning of these forms of *Rhizobium.* Initial results indicate that changes in cytochrome content and pattern, cell constituents, and respiratory activities occur when the nodule bacteria become associated with the host cytoplasm. The pattern of change is being related to changes in rates of nitrogen fixation of nodules from initiation to senescence. Attention is also being paid to respiratory pathways and terminal hydrogen transfer in bacteroids and cultured *Rhizobium.*

(iv) Rhizobium *Strains.*—The *Rhizobium* stock culture collection has been maintained, periodically tested, and expanded. A survey of the nodulation characteristics of *Lotus* has been commenced, and a survey has been made of the effectiveness of a number of strains of cowpea nodule bacteria isolated from the Katherine and Kimberley Research Stations in the Northern Territory with the aim of determining inoculation requirements in these areas.

(v) *Field Studies.*—Quantitative seasonal fluctuations of populations of *Rhizobium trifolii* in several soils of the Armidale district are being measured. The information provided may have a considerable bearing on nodulation of newly sown clovers in the area.

A comparison of symbiotic effectiveness on subterranean clover of *Rhizobium trifolii* isolated from beneath subterranean clover pastures and from beneath isolated subterranean clover plants in adjacent unimproved pastures in two areas near Crookwell, New South Wales, has shown that the strains from the improved pastures were of significantly lower effectiveness than those from unimproved land. This survey is being extended to ten sites on the Southern Tablelands and south-west slopes of New South Wales. It seems possible that lowered effectiveness of the bacteria from improved subterranean clover pastures may be a contributing factor in continued clover dominance.

6. GENERAL CHEMISTRY.

(Division of Plant Industry.)

(*a*) *Soil Fertility.*—Investigations on the influence of superphosphate and subterranean clover on soil fertility have been continued in the Crookwell district of New South Wales. Pasture improvement by this method has resulted in a marked build-up in soil fertility. There have been considerable increases in organic matter in the soils examined—frequently increases sufficient to more than double the original organic matter content have occurred over a twenty-year period.

The soil organic matter, both native and that accumulated as a result of pasture improvement, was found to have a relatively constant composition with a mean carbon: nitrogen: sulphur: phosphorus ratio of 155: 10: 1.4: 0.68. These results indicate that in these soils under the present fertilizer régime the rate of build-up of organic matter is limited by the amounts of sulphur supplied in the superphosphate top-dressings.

The accumulation of organic matter has resulted in marked increases in the cation exchange capacity of these soils. This has been accompanied by increases in the exchangeable cations, a decrease of pH, and beneficial changes in soil structure. Each hundredweight of superphosphate per acre has directly added 10.3 lb. of phosphorus and 13.4 lb. of sulphur and, through its stimulation of pasture growth, has indirectly led to an increase of 85 lb. of nitrogen, 25.5 lb. of exchangeable calcium, 6.5 lb. of exchangeable potassium, and 5.2 lb. of exchangeable magnesium per acre in the surface soil.

It seems most probable that rates of superphosphate heavier than those applied at present would result in increased rate of build-up of soil fertility.

(*b*) *Phosphorus Availability.*—Organic phosphorus, although unavailable to plants, could become available if mineralized, and work is now in progress to attempt the separation and estimation of organic phosphorus compounds from Australian soils. Work has initially been directed towards the extraction of organic phosphorus from soils and the subsequent identification of inositol hexaphosphate and the lower esters using paper chromatography and paper electrophoresis. Results using the latter have been the most satisfactory. Inositol hexaphosphate and small amounts of lower esters have been identified by both methods in extracts from a number of soils.

(*c*) *Sulphur Availability.*—Only a small portion of the total sulphur in soils is available to plants, and an examination of about 150 surface soils, mostly from eastern Australia, has shown that, in general, the amount of free sulphate comprises only a small proportion of the total sulphur. Non-sulphate sulphur has been found to be closely correlated with both total soil carbon and total nitrogen, which suggests that most of the soil sulphur may be present in organic forms. The relatively constant proportion of sulphur to carbon and nitrogen over this wide range of soils suggests that sulphur may be an essential constituent of the soil organic matter.

(*d*) *Spectrochemical Investigations.*—Laboratory and glass-house experiments have been commenced to investigate spectrochemically soil and plant factors concerned in the availability of " trace " metals to plants. Studies of the availability and uptake of copper, molybdenum, manganese, and iron indicate that both soil pH and iron oxides may influence the availability of molybdenum to plants.

(*e*) *Trace Element Availability.* (i) *Manganese.*—Studies of the availability of manganese to plants have continued. The work, consisting of both laboratory and pot experiments, has been carried out on two manganese-deficient soils from Penola and Rendelsham in the south-east of South Australia. These studies are of a long-term nature, but they have already thrown more light on the manganese cycle in soils and the uptake of manganese by plants. Studies are being made of the changes in manganese deficiency following liming of soil.

(ii) *Molybdenum.*—The availability of molybdenum to plants in soils is frequently increased by raising the pH. This relation to pH is analogous to that of phosphate when held in insoluble forms by iron and aluminium and suggests that molybdenum may be similarly held in soils. The reactions of molybdate in systems containing iron and aluminium are being studied.

7. PLANT NUTRITION.

(Division of Plant Industry.)

(*a*) *Soil Fertility.*—A number of soils were examined for major and trace element deficiencies. Responses of subterranean clover to potassium and copper, as well as to phosphorus, sulphur, and molybdenum, were obtained in pot cultures on some unimproved soils from the south coast of New South Wales. Failure of pasture over a large area at Rye Park, New South Wales, was found to be due to the combined effects of molybdenum deficiency and defective nodulation, and excellent results were obtained in field experiments on these soils with small amounts of lime and molybdenum.

Long-term experiments to measure effects of subterranean clover on soil fertility and crop production, and to measure residual effects of phosphorus, sulphur, boron, and molybdenum were maintained.

(*b*) *Nodulation of Legumes.*—Experiments on acid soils have provided further evidence that *Rhizobium* inoculum can be protected from the soil acidity by coating the seed with lime. Work done in co-operation with the New South Wales Department of Agriculture has shown that when the seeds are inoculated before pelleting, no viable rhizobia remain on the seed after four or five days. This opened up the problem of how *Rhizobium* might be introduced into the soil with lime-pelleted seed on a commercial scale. The results of experiments done on acid soils in pot cultures have indicated that good results may be obtained by dusting lime-pelleted seed with peat inoculum immediately before sowing. In these experiments the lime coating protected the *Rhizobium* when the seed was sown either apart from or in close contact with the superphosphate.

Ammoniated superphosphate prepared with ammonia gas and with ammonia liquor induced normal nodulation of clover on acid soils in pot cultures, but failed to induce nodulation in the field.

(*c*) *Role of Elements in Plants.*—In experiments using tomato plants and using a method of paper chromatography for determining the concentration of amino acids, results have been obtained which indicate that the elements molybdenum, iron, zinc, manganese, and copper differ in their effects on the free amino acid fraction in plants. In these experiments the concentration of free amino acids was decreased by molybdenum deficiency and increased by deficiencies of iron, zinc, manganese, and copper. Iron deficiency and zinc deficiency, unlike manganese and copper deficiency, markedly increased the concentration of the amides asparagine and glutamine. Iron deficiency and manganese deficiency increased the concentration of pipecolinic acid, while zinc deficiency and copper deficiency increased the concentration of β-alanine.

Work to define the metabolic reactions involved in the reduction of sulphate and nitrate in plant tissues and their incorporation into plant constituents has been continued. Using radioactive sulphur, labelled compounds formed in oat plants have been isolated, and the identification of these compounds is in progress.

8. MINERAL NUTRITION OF PLANTS.

(Division of Biochemistry and General Nutrition.)

The experiments have been continued to examine in greater detail the distribution of zinc in plants. Subterranean clover (*Trifolium subterraneum* var. Bacchus Marsh) was again used as the test plant, and was grown in culture solutions to which either no zinc was added or zinc was supplied in graduated amounts.

In these studies the plants were divided, according to growth stage, into leaf plus petiole, runner stems, roots, inflorescences, seeds, and burrs. In selected cases the leaves were separated from the petioles, old leaves were separated from young ones, and leaves showing the effects of zinc deficiency were separated from apparently healthy leaves. The results suggested that wide differences in dry weight and in the weight and concentration of zinc would be found among the leaves present on a plant at any one time, and that it would be necessary to examine individual leaves and petioles, at short intervals of time, to gain a clearer picture of the changing distribution of dry weight and of zinc in the leaves during the onset of zinc deficiency. The investigation has been completed.

In plants that were adequately supplied with zinc wide differences were observed between the weights of individual leaves, and of the concentrations of zinc present in them at any one time. The zinc content of each leaf on these plants began to decrease after it had reached a maximum, but the dry weight of the leaf did not decrease during the period of observation. Maximum zinc content of the leaf was reached before maximum dry weight. In zinc-deficient plants, on the other hand, an abnormal increase in the dry weight of the oldest leaves took place during the onset of the deficiency, and the opening leaves neither accumulated zinc, nor lost it. The continuing increase in the dry weights of the oldest leaves on these plants was at first sufficient to compensate for the reduced growth of young leaves, so the overall production of dry matter was not affected during the early stages of the deficiency.

All the combinations of the changes in dry weight and zinc content referred to above brought about a decreasing concentration of zinc in the leaves as they emerged and began to unfold. Thus it can be argued that the concentration of zinc in the leaves may be higher before emergence than afterwards. Radioautographs showing the distribution of ^{65}Zn in the plants in another experiment indicate that this is so in zinc-deficient plants as well as in plants that are adequately supplied with zinc.

The rate of fall of the concentration of zinc in an individual leaf after emergence has been found to be as much as 2 p.p.m. zinc per day. This stresses the importance of the time factor when attempts are made to reveal in the plant or any of its parts the concentration of zinc at which the onset of zinc deficiency occurs. Up to the present a distinctive chlorosis in the unfolding leaf has been regarded as a first sign of zinc deficiency. The chlorosis is not to be seen in its initial stages in the intact plant, however; it is already present when the leaflets open. Certain morphological changes which take place in developing leaves as a result of zinc deficiency also do not become apparent in the intact plant until the affected leaves have expanded and begun to emerge. Thus symptoms of zinc deficiency may not be recognizable on the intact plant until an appreciable time after metabolism has become affected.

A definition of zinc deficiency is required now in terms of the earliest recognizable symptoms that result from the disordered metabolism. To this end it is proposed to examine the effects of zinc deficiency on the development of leaves prior to the time of their emergence.

Recognition of symptoms of zinc deficiency and a full appreciation of what they imply are of primary importance to the husbandry of pastures on zinc-deficient terrain.

9. PLANT PHYSIOLOGY.

(Division of Plant Industry.)

(*a*) *Growth Regulators.*—(i) *Mechanism of Auxin Action.*—A Californian school has applied enzyme kinetics to growth rates of *Avena* coleoptiles in auxin solutions, and given support to the theory that growth results from the chemical attachment of auxin at two points to a receptor site. However, controversy has arisen as to whether, in high auxin concentrations, growth is linear with time (as this school finds) or falls off after an initial high rate (as others find). It was found that growth linear with time, in high auxin concentrations, could not be achieved under any conditions. However, after an initial burst at a high rate for three hours, rates became constant for the following eight hours. These steady rates conform to the requirements of the two-point attachment theory. In attempting to explain the high initial growth rates, wide variations in methods of culturing both the seedlings and coleoptile sections (particularly with reference to calcium and total salts) were employed. The same type of growth curve always resulted.

(ii) *Leaf Growth.*—Since the leaf is the factory of the plant it is important that the factors controlling its growth be understood.

Indole-3-acetic acid was found to increase the growth of both the veins and petioles of leaves according to a similar pattern. The light régime in which the test plants were cultured, but not that of the test itself, changes the concentration optimum for growth. Kinetin and gibberellic acid had no effect on extension of veins and petioles.

Work has commenced on the recognition of factors which may control leaf blade (lamina) growth.

(*b*) *Seed Physiology.*—(i) *Dormancy in Subterranean Clover and Other Legumes*—Information on the effect of carbon dioxide (CO_2) in breaking dormancy of subterranean clover has been extended by studying temperature relationships. The efficiency of CO_2 declines sharply at temperatures above 25° C., and is virtually nil above 30° C. This fact has allowed a unifying hypothesis concerning the germination and dormancy of seeds of the species to be formulated.

The dormant seed of five other legumes (*Trifolium* spp. and *Medicago* spp.) responded qualitatively similarly to CO_2, i.e. CO_2 was at least as good as, and in most cases better than, low temperature in relieving dormancy. It is possible that these facts could be put to use in seed testing practice.

(ii) *Germination Inhibitors.*—Further work with extracts of *Echium* material has shown that two germination inhibiting components are present—one inhibits *Echium* seed but not cress seed, the other inhibits cress but not *Echium* seed. This criss-cross pattern could represent an interesting species adaptation mechanism.

(iii) *Light Sensitivity.*—Some seeds require light stimualation before they can germinate; for others light is inhibitory. The seeds of *Anagallis arvensis* apparently belong to the latter class. However, if the light is filtered to leave only red rays (approximately 650 mμ) germination is promoted; but if filtered to leave the deep red rays (approximately 720 mμ) germination in inhibited. The behaviour of light-sensitive seed must therefore depend both on the relative amounts of red and deep red radiation in the light, and the relative sensitivity to each of these.

(*c*) *Photoperiodic Requirements of Subterranean Clover.*—Work has commenced on the determination of minimal effective photoperiodic stimuli required for flowering by the several varieties of this species. Less is known of this than the graded requirements which the varieties have for an exposure to low temperature.

(*d*) *Protein Synthesis in Developing Wheat Grains.*—It is known that flour quality is related to protein content of the endosperm, and that wheat quality is affected both by the environment and nutrition. However, little is known about the actual protein synthesis in the grain and the effect of this on quality.

This work is designed to study protein synthesis under controlled conditions—both *in vivo* in developing grains on the plant, and, *in vitro* by culturing young endosperm tissue. The latter enables the effect of a wide range of biochemical environments to be studied. Methods appropriate for this study have now been elaborated.

(*e*) *Embryo Nutrition.*—Because the embryo is a miniature whole plant, studies of it help in understanding plant metabolism. Recent work has shown that:—

(i) Nitrate does not (or does so only poorly) support embryo growth, in contrast to the good response obtained with single amino acids, and, in many cases, ammonia.
(ii) L-alanine stimulates embryo growth in *Arabidopsis thaliana;* but the D-isomer is inhibitory.
(iii) Allantoin stimulates embryo growth in many species.
(iv) In *Anagallis arvenis* γ-aminobutyric acid elicits no embryo growth response; but L-alanine and L-glutamic acid do.

(*f*) *Soil Fertility.*—Experiments to study the effect on soil fertility by the addition of large quantities of organic matter to the soil as gauged by crop growth and nutritional requirements have been initiated. Results from Griffith, New South Wales, have shown that crop growth was stimulated by an increased intake of phosphorus from the soil following the addition of organic material. The source of this additional phosphorus and the soil and plant factors determining its release are being investigated, using phosphorus deficient soils to which phosphate minerals had been added. Rice hulls and glucose are the organic materials being used.

(*g*) *Seedling Growth.*—A programme of work on the physiological and morphogenetic factors determining the number and size of leaves on the vegetative plant axis has been initiated. This will lead to a fuller understanding of plant responses to nutrient deficiency, drought, disease, and defoliation. Studies have been made for the French bean and wheat. In both cases the distribution of seed reserves was at its peak on day 6 and had almost ceased by day 12. The data indicate the critical nature of the change from dependence on seed reserves to dependence on the environment for all raw materials.

The growth of the successive leaves of the primary shoot of wheat is being analysed in terms of cell size, cell number, organ volume, and dry weight.

10. BIOCHEMISTRY AND BIOPHYSICS.

(Division of Plant Industry.)

(*a*) *Cell Growth and Differentiation.*—Studies of the determining factors in the initiation of cell division and of cell growth and differentiation in higher plants have continued.

(i) *Aseptic Cultivation of Isolated Roots of Subterranean Clover.*—The main axis meristem and the lateral meristems have different growth characteristics which determine the morphology of the root system. It has been shown that the mechanism which changes the cell division rate in lateral roots arising in the pericycle can be triggered by L-tryptophan (7.5×10^{-5}M), plus L-histidine (2×10^{-5}M), plus L-arginine (3×10^{-4}M) at concentrations which do not promote the main axis meristem. A similar change may be initiated by 2, 6-diamino purine ($3 \times 10^{-8} 3 \times 10^{-5}$M) in the presence of some substance from the aerial part of the plant; at these concentrations the growth of the main axis meristem is inhibited.

Amino acid requirements of the root system have been studied in detail. Only very low concentrations of individual amino acids are tolerated. Added arginine not only protects against growth inhibition, but enhances the utilization of other amino acids.

(ii) *Isolated Flax Hypocotyls.*—Isolated hypocotyls from flax seedlings cultivated aseptically on defined media may regenerate by producing adventitious buds, from single epidermal cells, or adventitious roots, usually from the pericycle. It has been found that bud formation is promoted by red light and that root formation is promoted by auxins and by *NN′*-diphenyl urea. The mechanism of these processes is being studied.

(*b*) *Oxidation of Inorganic Sulphur Compounds by Soil Microorganisms.*—The mechanisms whereby microorganisms convert inorganic sulphur compounds to inorganic sulphate are being studied.

(i) *Oxidation of Thiosulphate by* Pseudomonas aeruginosa.—Washed suspensions of *P. aeruginosa* oxidize thiosulphate; tetrathionate has been identified as the end product of the reaction by chromatographic and chemical techniques. The stoichiometry of the reaction has been established manometrically.

(ii) *Oxidation of Thiosulphate and Tetrathionate by Thiobacillus X.*—It has been established that Thiobacillus X oxidizes thiosulphate and tetrathionate completely to sulphate and that tetrathionate is produced from thiosulphate under certain conditions; the latter may occur through a side reaction.

The addition of thiosulphate to whole cells, dried cells, or certain extracts of Thiobacillus X results in the reduction of certain cytochromes to the ferrous state. These are being isolated so that their role in thiosulphate oxidation can be investigated.

(*c*) *Chromatography of Tobacco Mosaic Virus* (*T.M.V.*).—A study has been made of the behaviour of T.M.V. on columns of the ion-exchange resin " Cel-SPX ", prepared by coating particles of " Celite 545 " with sulphonated polystyrene. Some preparations were reversibly adsorbed on the resin from buffers of pH 5.2-5.5 and sodium ion concentration 0.50 g ions/1., and these could be successively chromatographed on columns of " Cel-SPX ". The chromatographic behaviour varied with different preparations of the virus, and no preparation was chromatographically homogeneous.

In attempts to standardize the method of preparation, it was found that exposure of the virus during preparation to solutions more acid than pH 6, and heat treatment at 60°, produced changes in chromatographic behaviour. This appeared to be due to variations in the state of aggregation of the virus. A detailed study of the aggregation and its effect on the chromatography will be made.

(*d*) *Nucleotide Biosynthesis.*—The biosynthesis of adenylic acid is being studied with the aid of the adenine-requiring mutant No. 44206 H_{2a} of *Neurospora crassa,* in which the metabolic block occurs subsequent to hypoxanthine and prior to adenine formation. Two compounds, namely, 6-(α, β-dicarboxyethylamina)-purine (" adenine-succinic acid ") and its riboside, have been identified as products which are accumulated in the growth medium of this mutant as a result of the metabolic block. Adenyl-succinic acid, the ribotide of the above compound, is an intermediate in the *in vitro* conversion of inosinic acid to adenylic acid. In the *in vivo* system it seems possible that the ribotide is the primary product of the metabolic block, and that adenine-succinic acid and its riboside are derived from it. Preliminary examinations, however, have not yet revealed the presence of adenyl-succinic acid.

(*e*) *Plant Pyrrol Pigments.* (i) *The Function of Haemoglobin and Other Haem Pigments in Legume Root Nodules.*—Freshly prepared crushes or homogenates of the nodules formed by " effective " *Rhizobium* strains on roots of the soybean have an absorption spectrum characteristic of oxyhaemoglobin; on standing in the absence of air, an absorption band characteristic of reduced cytochrome *c* appears.

The subcellular components from these homogenates were separated by differential centrifugation. All of the haemoglobin, and no other pigment, was in the supernatant from centrifugation at 140,000 g. Although a small mitochondrial fraction showed the normal cytochrome spectrum (components *a, b,* and *c*), a great deal more cytochrome *c* appeared in the " bacteroid " fraction; while this was very high in cytochrome *c,* it contained little cytochrome *b* and no detectable *a.* The same strain of *Rhizobium,* grown in artificial culture (now not capable of nitrogen fixation), possessed cytochromes *a, b,* and *c* in the same order of concentration as seen in animal or plant mitochondria.

Preliminary observations have shown the same peculiar cytochrome pattern in the " bacteroids " from effective root nodules from other varieties of legumes, but the cytochrome *a, b,* and *c* pattern in several *Rhizobium* strains grown in artificial culture, and in rhizobia isolated from " ineffective " (i.e. non nitrogen-fixing) root nodules. Haemoglobin was not found in any of the artificial cultures or in the " ineffective " nodules.

(ii) *Porphyrins and Porphyrin Biosynthesis in Legume Nodules.*—In addition to haemoglobin and cytochromes, " effective " soybean nodules contain free porphyrins in relatively very high concentration. The ether-soluble porphyrins appear to consist of protoporphyrin and coproporphyrin III. The ether-insoluble fraction is the major component; this mixture of porphyrins contains little or no uroporphyrin.

The " ineffective " soybean nodules, which contain no detectable haemoglobin, contain no detectable amount of free porphyrins. Incubation of these nodules, either intact or homogenized, with intermediates for porphyrin formation (glycine; δ-aminolaevulic acid; porphobilinogen) led to no formation of porphyrins. It appears possible that one factor determining " ineffectiveness " may be a block to the symbiotic synthesis of tetrapyrrole nuclei.

(iii) *Effect of Oxygen Tension on Porphyrin Biosynthesis.*—As a model system for the oxygen adaptation of bacterial cytochromes, the effect of oxygen tension has been studied on the synthesis of porphyrins in chicken erythrocytes. When intact erythrocytes were incubated with glycine, coproporphyrin formation was maximal at about 0.01 atm, and protoporphyrin formation at about 0.07 atm of oxygen. Protoporphyrin formation was sub-optimal at the O_2 tension of air (0.2 atm) and was suppressed to about 50 per cent. of the optimal amount at 0.95 atm (95 per cent. O_2, 5 per cent. CO_2).

(*f*) *Studies of Alkaloids and Glucosides.* (i) Duboisia.—The alkaloid $C_8H_{15}NO.HCl$, obtained from *Duboisia myoporoides* from Acacia Plateau on the Queensland-New South Wales border was identified as *iso*pelletierine ((2-piperidyl)-acetone). Examination of single tree samples showed that, in general, trees in this area all contained nicotine, hyoscine, anabasine, and *iso*-pelletierine.

(ii) *Cyanogenetic Glucosides.*—A method has been developed for the detection of cyanogenetic glucosides on paper chromatograms. Work on adaptation of the method for use with plant extracts is proceeding.

(*g*) *Availability of Manganese Oxide to Oats.*—Sterile oat plants release substances which can dissolve manganese dioxide. These substances are also present when the plants are grown normally in sand and in a manganese deficient soil. Whilst manganese oxide is completely available in sand it is only slightly available in the deficient soil. This suggests that the soil has a mechanism for rendering the dissolved manganese unavailable.

(*h*) *Studies of Auxins and Antiauxins.* (i) *The Acid Strength and Ultra-violet Spectra of Phenoxy-type Acids.*—A study has been made of the u.v. spectra and acid strength of a number of chlorinated phenoxyacetic acids and of their phosphonous and phosphonic acid analogues. The effect of ionization on the u.v. spectra has been determined, and interpreted in terms of an electrostatic interaction between the ionizing group and the electrons associated with the phenolic oxygen.

(ii) *Translocation of Auxins and Poisons.*—The former finding, that the translocation of orthoarsenic acid in skeleton-weed does not appear to depend on the simultaneous movement of carbohydrates, has been confirmed. The same result has been obtained for the translocation of 2,4-D. The translocation of orthoarsenic acid in skeleton-weed is not affected by increased or reduced oxygen tension. Boron, normally considered important in translocation, does not improve the kill of skeleton-weed roots by 2,4-D.

(iii) *Fluoro-derivatives of 2 : 4-Dichlorophenoxyacetic Acid (2,4-D).*—α-difluoro-2,4-dichlorophenoxyacetic acid and its ester caused some auxin response, giving further evidence that an α-hydrogen is not necessary for auxin activity.

(*i*) *The Effect of Detergents on Plant Tissue.* (i) *Mode of Action of Detergents.*—The well-known lytic action of detergents on the red blood cell prompted an investigation into the action of detergents on plant cells. Both cationic, and less effectively, anionic detergents will kill the *Nitella* cell over a period of time; from bio-electric potential measurements and from microscopic examination the effect appears to be associated with the rupture of the plasmalemma in a manner analogous to the haemolytic action of detergents. Experiments are continuing to locate and characterize the membrane postulated to be destroyed.

(ii) *The Effect of Detergents on Pea Sections.*—The effects of the detergents, sodium dodecyl sulphate and dodecyltrimethylammonium bromide, on pea sections were studied using the lowhigh frequency resistance ratio technique as a guide to the injury.

Preliminary results indicate that whilst the cationic detergent is highly toxic at 10^{-3}M and fairly toxic at 10^{4-}M, its anionic counterpart is without effect at these concentrations.

(*j*) *Membrane Studies on* Nitella. (i) *Membrane Potential Measurements.*—The time course of the plasmalemma potential difference, following changes in the KCl concentration and pH of the solution bathing the cell, has been followed. The results were both complex and variable, and no satisfactory theoretical treatment has been possible.

To further these investigations, radioactive tracer experiments are being planned, which it is hoped will throw light on the " apparent free space ", and on ion fluxes across the plasmalemma of *Nitella.*

(ii) *Membrane Resistance Measurements.*—Direct evidence of the existence of a functional (i.e. partly impermeable) plasmalemma in *Nitella* was sought by measuring electric resistances in the cell with direct current. The presence of a significant electric resistance between the cell sap and the outside medium, and between the cell cytoplasm and the outside medium, indicated the presence of a membrane, i.e. a layer retarding the passage of ions.

(*k*) *Measurement of Injury in Plant Tissues.* The low frequency/high frequency resistance ratio method of measuring injury was used to determine differences in frost hardiness between individual white clover plants. The magnitude of the ratio after frost treatment is correlated with the probability of recovery of the plants.

The same method has been used to test heat susceptibility of a number of strains of *Phalaris.* Results indicate that different strains and even different tillers of the one plant differ in their susceptibility.

Similar work is being undertaken on drought injury of subterranean clover.

11. PLANT ECOLOGY.

(Division of Plant Industry.)

(*a*) *Rain-forest Ecology.*—The reconnaissance of the east Australian rain-forests has been completed. Microclimate and hydrological measurements in the Whian Whian State Forest, New South Wales, have been continued in co-operation with the Division of Soils, C.S.I.R.O., and the New South Wales Forestry Commission. These measurements will help to provide a quantitative description of different stages of succession in vine and sclerophyll rain-forest.

(*b*) *Alpine Ecology.*—Investigations on high mountain ecology have continued with special reference to catchment hydrology and its modification by land use. An ecological reconnaissance of the high mountains environment including studies of climate, physiography, geology, flora and fauna, soils, and land use has been completed. The effects of summer grazing and burning on high mountain catchment areas is being studied by means of permanent run-off plots from which water yield and soil movement can be measured. Other hydrological properties of the vegetation being measured are the accumulation and persistence of snow and the effect of sphagnum bogs on the yield and duration of flow of water.

(*c*) *Ecology of Subalpine Grasslands.*—Studies of the origin of treeless grasslands in the subalpine areas of New South Wales are nearing completion. The tolerance of tree-line eucalypts to low temperatures has been determined experimentally and is in close agreement with their topographical distribution.

(*d*) *Ecological Studies—Southern Tablelands of New South Wales.* (i) *Vegetation Survey—Southern Tablelands of New South Wales.*—Work on this project will be concentrated on the Yass River Valley as part of the geographical, agricultural, and economic survey at present in progress in this area.

(ii) *Autecology of* Bothriochloa ambigua.—Studies of factors concerned in the spread of the unpalatable red grass (*Bothriochloa ambigua*) in native grasslands of the tablelands of New South Wales have continued. Experiments have indicated that the invasion of a vigorous *Danthonia* grassland by *B. ambigua* is unlikely, but that a weakened *Danthonia* sward and bare areas may be colonized by the latter species. Present evidence suggests that this is related to the more vigorous root development of *B. ambigua.*

(iii) *Microclimates and Topography.*—The variations in microclimates of different slopes and aspects are being studied to determine the possibility of increasing pasture production in different seasons of the year by using the more climatically favoured sites. It has been shown that there are marked differences in the growth of oats on different aspects on a small hill in the Canberra plain. It is proposed to extend the scope of this work when suitable instruments are available.

(iv) *The Distribution of Native Plant Communities in Relation to Soil Nutrients.*—The nutrient status of the soils of three pairs of communities is being investigated in the glass-house with oats as a test plant. It has been found that the soils of *Eucalyptus rossii* communities contain more available phosphorus than do those of *E. melliodora* and *E. pauciflora.* The status of other major and minor nutrients in the soils of the different communities is also being investigated. The objective of the investigation is to determine whether the local distribution of different species of eucalypts is related to the nutrient status of soils.

(*e*) *Vegetation Survey of Macquarie Region, New South Wales.*—A vegetation survey of an area of approximately 4,800 square miles in the Macquarie region of New South Wales has been completed. The plant communities have been classified and the principal climatic and edaphic factors concerned in their distribution have been determined. Investigations were also made of the effect of present land use on the different communities, particularly in relation to the grazing factor.

(*f*) *Ecological Studies—Semi-arid Grasslands.*—The grazing management experiment conducted in cooperation with the New South Wales Department of Agriculture has been completed. The proposed investigation of the use of grazing lucerne as a supplement to native semi-arid grassland has been postponed indefinitely.

It is proposed to use the Regional Pastoral Laboratory, Deniliquin, New South Wales, as the Division's main centre for studies on semi-arid grasslands. Studies will be made of the germination and seedling establishment requirements of useful native grasses and of weeds with the objective of determining how grasslands in good condition can be utilized for grazing purposes without degeneration, and how those in poor condition can be regenerated.

(*g*) *Arid Zone Ecology.*—It is proposed to undertake ecological studies along a transect running from Deniliquin to Broken Hill. Particular attention will be given to the germination and seedling establishment requirements of native species and of the microenvironments of preserved and degenerate native plant communities. It is proposed also to investigate soil salinity as a factor in plant distribution.

(*h*) *Ecological Studies on Weeds.*—(i) *Distribution of Introduced Plants in South-eastern Australia.*—The distribution of a large number of introduced weeds has been investigated and their climatic ranges in Australia are being compared with those of the countries of origin. The effects of temperature on the germination of a number of species has been studied, and the relationship of temperature requirements to distribution of the plants is being investigated.

(ii) *The Biotic Factor in Plant Succession.*—The effect of one species on another is being investigated, both at Canberra and in the rain-forests of northern New South Wales. At Canberra some weeds have been tested to determine the effects of germinating seed of one species on germination and establishment of another.

(iii) *Competition between Skeleton-weed* (Chondrilla juncea *L.*) *and Cereal Crops.*—A study of the competition between skeleton-weed and cereals in relation to nitrogen supply has been completed. It was found that spraying skeleton-weed with selective herbicides 30-50 days before sowing wheat, or in the seedling stage of oats, reduced the competition between skeleton-weed and the cereal for nitrogen, and resulted in much higher grain yields than the normal commercial spray applied in the spring.

(iv) *Competition between Pastures and Skeleton-weed.*—It has been shown that the density of skeleton-weed can be reduced by pasture plants such as subterranean clover, and it is thought that after 3-4 years under a temporary ley it may be possible to grow one or more high-yielding cereal crops before the skeleton-weed density again builds up to high proportions. Experiments in progress at Cowra, New South Wales, this year will provide evidence on this point.

(v) *Competition between Hoary Cress* (Cardaria draba) *and Cereals.*—The practical control of hoary cress in the Victorian Wimmera has been clearly demonstrated. Two or more like applications of 2,4-D type herbicides reduced the hoary cress density to low levels, succeeding applications being more effective than the preceding one. The lowering of cress densities resulted in higher cereal yields. The competitive effect of Wimmera ryegrass on hoary cress has been demonstrated both in the field and in the glass-house.

(vi) Nasella trichotoma (*Yass River Tussock*).—Earlier work has shown that sodium trichloracetate was effective in the control of tussock at economic rates of application. However, the dependence of this herbicide on following rains limits its general application and later work has been directed towards the finding of compounds chemically related to sodium trichloracetate which are not dependent on rain for their effectiveness. Since subterranean clover pastures are not invaded by tussock, attention has been given to methods of effectively establishing subterranean clover on rough hilly country.

(vii) *Control of Aquatic Weeds.*—Work in the Murrumbidgee Irrigation Areas has shown that the impedance to the flow of water in farm ditches by the inflorescences of *Paspalum dilatatum* can be removed by spraying with maleic hydrazide. This compound has the advantage that it merely delays the formation of seed heads and does not kill the plant, thus there is no disturbance to the ditch, nor invasion by other species. Investigations on the control of cumbungi (*Typha*) species in main drainage channels have shown that 2,4-D at 6 lb. per acre is effective and that its effectiveness is increased by maintaining a high water level in the channel subsequent to spraying.

(viii) *Control of Eucalypt Regeneration in Fire-breaks.*—The problem of the regeneration of eucalypts by suckering following the bulldozing of fire-breaks continues to be investigated. Co-operative studies with the Australian Forestry and Timber Bureau have indicated that ammonium sulphamate (ammate) is of considerable promise in controlling regrowth.

(ix) *Mistletoe Investigations.*—Field tests have been continued on a reduced basis with the Forestry and Timber Bureau. Although difficult to apply, the hydrazine salt of 2,4-D has given the best results. An improved formulation is being sought.

(x) *General Weed Control.*—The potentialities of some new herbicides, such as CMU, "Dalapon", and aminotriazole are being investigated. A study of the persistence of CMU in relation to clay and organic matter content of soils has been completed.

12. FRUIT INVESTIGATIONS.

(Division of Plant Industry.)

(*a*) *At Hobart.* (i) *Physiology of Apple Fruits in Relation to Storage Disorders.*—Experiments to study the effect of individual growth substances applied at full bloom on fruit cell division and fruit size have been continued. The interrelationship between seed and fruit development in their competition for substances necessary for cell division appears to be of importance in determining keeping quality, and there is evidence that effects of growth substances on cell division in apple fruits may have operated through seed suppression. Studies of locality differences in the relationship between disorder incidence and fruit size have continued.

Proof that high nitrogen treatment can increase disorder incidence independent of any fruit size effect has been obtained. High nitrogen does not affect the respiration rate in the preclimacteric period, and if the injurious effects of high nitrogen operate through respiration it must be in the climacteric phase.

(ii) *Apple Scald.*—Further experiments have confirmed the high degree of control of apple scald by diphenylamine applied as a wrap or dip, and have extended the range of varieties responding. Lack of information on toxicity is the only factor preventing commercial adoption. Substitute materials of known toxicity have not been sufficiently effective to displace diphenylamine. The mode of operation of the substance is still unknown.

(iii) *Gas Storage.*—A chamber of 2,000 boxes was made available by a commercial firm to test the Venturi Scrubber and low oxygen storage under commercial conditions. The scrubber performed well, and it was possible to maintain oxygen concentrations as low as 3 per cent. and carbon dioxide below 0.5 per cent. Milk of lime, which is cheaper and safer than caustic soda, was shown to perform satisfactorily in the scrubber.

(iv) *Asymmetrical Growth in Cleopatra.*—Preliminary experiments with growth substances gave negative results, owing partly to generally lower response in 1956. It now appears that poor seed development may not be the controlling factor.

(v) *Maleimides as Defoliants.*—Preliminary trials were made to test the responses of hops to *N*-1-naphthylmaleimide and *N*(2,4-dichlorophenyl) maleimide with the idea of assisting in mechanical harvesting. These substances had little effect on leaf abscission in three varieties, and there was some injury to plant and flower by the substances and solvents.

(*b*) *At Applethorpe, Queensland.* (i) *Rootstock Investigations.*—A survey of rootstocks used for plums has begun with the view to selecting types from trees of outstanding production, and selecting some which are suitable for shallow as well as for deeper soils.

Apple rootstock trials are being continued. The younger trials with the Merton and the Merton-Malling immune stocks are now at the cropping age but will need three to four years longer before a preliminary report will be justified.

An investigation to determine whether storage life and the incidence of storage disorders of fruits is influenced by rootstock or by fertilizer applied as a soil dressing in spring or as a foliar application in summer has been commenced.

(ii) *Apple Physiology.*—Using two apple varieties, Jonathan and Granny Smith, a series of sprays including urea and sugar plus borax were applied during the summers of 1956 and 1957. Urea sprays delayed the colour change of the skin and starch conversion to sugar in the cortical tissue, while the sugar-borax sprays hastened the change in ground colour in Jonathan fruits and caused an earlier starch conversion and an earlier abscission of fruits in the Granny Smith variety.

13. TOBACCO INVESTIGATIONS.

(Division of Plant Industry.)

(*a*) *Genetics.* In the breeding programme for resistance to blue mould work has been concerned with the location and transfer of resistance to commercial varieties of tobacco. Hybrids have been obtained with *N. goodspeedii, N. excelsior, N. debneyi*, and *N. megalosiphon.* Backcrosses from *N. goodspeedii* and *N. debneyi* to *N. tabacum* are showing considerable promise, one line in particular combining high field resistance with large leaves, although the leaf is unsuitable for curing.

In addition an attempt is being made to induce resistance in a commercial variety by chemical mutagens or radiation, combined with testing by artificial inoculation. Thirty-five thousand first generation plants from X-irradiated seed or ultraviolet treated pollen all proved highly susceptible. Testing of second generation plants is now in progress.

(*b*) *Diseases and Disorders.* (i) *Blue Mould.*—A field survey of disease incidence has shown that severity varies with location. It has been shown that total leaf area affected by the disease, the potentiality of diseased leaves for promoting further spread of the fungus, and leaf maturity are related directly to soil type. It has been shown that severity of the disease increases in plants approaching flowering if leaves are kept moist. This effect is not apparent in plants less than 18 inches high.

A survey of the Mareeba-Dimbulah and Burdekin River areas has shown that control of the disease in seed beds is not always adequate. In most cases this is due to insufficient application of benzol. Glass-house tests have shown that effective control can be obtained with benzol even when the plants have been infected for as long as five days.

(ii) *Frenching.*—The factor responsible for frenching of tobacco has been obtained from Katherine soil. Frenching occurred in plants growing in water extracts of the soil, although it did not occur in plants grown in water extracts from sand or vermiculite causing frenching. Separation of the frenching factor from sand was obtained after addition of non-frenching soil.

(iii) *Sporulation of* Peronospora tabacina.—A quantitative technique based on the measurement of intensity of sporulation per unit area of leaf has been developed. Relative humidity, diffusion pressure deficit, temperature, and light have all been shown to have critical levels in terms of both intensity and duration of time in relation to the development of conidiophores and conidia *in vivo.* Mechanical shock and change in relative humidity have both been shown to be factors in the release of spores from conidiophores. Significant differences have been shown between plants of different ages and sporulation intensity. Preliminary results comparing the sporulation of several tobacco varieties under optimum and sub-optimum conditions indicate that sporulation rate is a varietal characteristic. This work is important for the control of blue mould epidemics and in the selection of tolerant varieties.

(iv) *Respiration of the Starving Tobacco Leaf.*—The metabolism of the detached leaf starving in water in the dark has great relevance to tobacco curing, the " yellowing " stage of which is a controlled starvation.

The starving leaf shows a respiratory " climacteric " during yellowing. Changes in some respiratory pathways during starvation were studied by direct assay of oxidative enzymes and also by inhibitor studies. Tobacco leaves of the flue curing type were used.

(*c*) *Leaf Structure and Quality.*—Work has commenced on an examination of cured tobacco leaf in an attempt to relate structure and quality. Structural characteristics responsible for variations in texture important in grading will be determined and related to structure in the green leaf.

(*d*) *Nutrition.*—Investigations on potassium nutrition were continued at the Waite Agricultural Research Institue, Adelaide. Special attention was given to an examination before and after curing of leaf from plants grown in nutrient sand culture at three levels of potassium nutrition. Yields of leaf were similar but at lower levels there were some symptoms of deficiency. After curing, leaves from the low potassium treatment were dark and brittle, leaves from the intermediate treatment were bright with dark brittle patches round the margin and the tips, and leaves from the high treatment were bright and of good texture.

An attempt is being made to elucidate the differences obtained by comparing the carbohydrate, amino acids, and chlorogenic acid content before and after curing.

14. Pasture Investigations, Canberra.

(Division of Plant Industry).

(*a*) *The Pasture in Relation to Animal Requirements.*—The widespread conditions of marked fluctuations in pasture growth during the year and between years have the effect of restricting the number of animals that can be carried, of limiting the productivity per head, and yet of leaving a large proportion of the annual pasture growth unconsumed. The purpose of these investigations is to examine the pasture-animal complex with a view to defining (i) the characteristics of plants which affect animal production and (ii) the factors of grazing which affect the pasture. To this end studies are being made of a variety of pastoral procedures in order to evaluate their worth and to provide a wide range of pasture-animal conditions.

(i) *Comparison of Native and Sown Pastures.*—The ability of well-fertilized sown pastures to provide planes of nutrition for the breeding ewe superior to those from native pasture continues to be examined. As a subsidiary to this experiment it has been found that the number of lambs born to a ewe has no direct bearing on subsequent milk yield, but that the number of lambs suckled has a very real effect.

(ii) *Special Purpose Pastures for Summer and Winter.*—The standard pasture of *Phalaris tuberosa* and subterranean clover, whilst highly productive and persistent—even under hard grazing—is deficient in quantity of herbage produced in the winter and in quality in the summer. The potentialities of other species for fodder production during these deficient periods are being investigated. Four winter growing and four summer growing perennial grasses have been sown. The production of sheep on these pastures will be compared with that of *Phalaris tuberosa* during the winter and summer in order to compare both grazing and production capacity.

(iii) *Pasture Management for the Ewe.*—Three systems of pasture management—each at two stocking rates, and at two types of pasture—are being compared for their ability to provide grazing at times and in quantity of most benefit to the ewe during pregnancy and lactation. The effect is being measured in terms of birthweight and live-weight gain of the lamb and the behaviour of the pasture in relation to subsequent animal production. The etiology of pregnancy toxaemia has been studied in cooperation with officers of the Division of Animal Health and Production.

(iv) *Artificial Nitrogen for Increased Winter Production of Pasture.*—An increase in the winter production of sown pasture by applications of fertilizer nitrogen has not substantially increased animal production to date. Nitrogen-fertilized *Phalaris tuberosa* pastures appear to be unpalatable to the grazing animal in the winter.

(v) *Crops for Supplementary Animal Feed.*—A comparison is being made of sheep grazing solely on pasture, on pasture in rotation with a grazed crop, and on pasture in rotation with a salable crop. Preliminary results suggest that growing a crop to provide animal grazing when pasture growth is deficient lowers animal production because of the lesser amount of pasture available while the crop is being prepared and grown. This is not compensated by the subsequent greater amount available from the crop itself.

(vi) *Pasture Conservation.*—Cutting for hay or silage involves heavier grazing intensities on complementary areas whilst the conservation measures are being carried out. The long-term effects of these procedures are being measured in terms of qualitative and quantitative response of the pasture and its effect on sheep—both wethers, and breeding ewes and their lambs. The degree to which the increases in meat and wool production achieved by conservation are dependent upon changes in the pasture, or are due to the feed-back of the conserved material, is being examined.

(*b*) *Other Pasture Investigations.* (i) *The Effect of Defoliation on* Phalaris tuberosa.—To determine the characteristics of pasture grasses which enable them to withstand heavy and frequent defoliation, the effects of defoliation on strains of *Phalaris* having different periods of maturity are being investigated. Particular attention is being paid to the origin of tiller buds and the effects of defoliation on their number and place of origin.

(ii) *Soil Fertility Studies.*—The phosphorus and nitrogen status of the wheat-growing soils of the Riverina was investigated at several sites. Growth of cereals at Ariah Park was found to depend on nitrogen availability as influenced by the presence of skeleton-weed (*Chondrilla juncea*). In the Canberra environment the likely major controlling factors, temperature and cultivation, are being investigated on an established lucerne sward. The general nitrogen availability on break-up of *Phalaris tuberosa*-subterranean clover pasture is also being examined.

(iii) *Medic Investigations.*—The possible use of annual species of *Medicago* as a basis for temporary leys in the New South Wales wheat belt is being investigated. Species of *Medicago*, principally *M. hispida* var. *denticulata* and *M. minima,* already naturalized in this area, have sporadic growth and the burrs are objectionable in wool. Attention is being paid to *Medicago tribuloides* (barrel medic), the burrs of which have straight spines and are therefore less troublesome in wool.

The nutrient requirements of barrel medic and the conditions necessary for its germination and establishment are being investigated. Strains from various parts of Australia and overseas have been grown and are being classified and described. The soil nitrogen increase after medics is being investigated by the response of following wheat crops at Crooble, N.S.W.

15. PASTURE INVESTIGATIONS, ARMIDALE.

(Division of Plant Industry.)

(*a*) *Species and Strains.*—Grasses showing promise for pasture improvement in the southern part of the New England region have been *Phalaris tuberosa* for winter and Kentucky 31 tall fescue for summer. In the more eastern localities *Phalaris arundinacea* has been outstanding in summer. Wimmera ryegrass has shown high winter production. Growth rate comparisons have been made between *Phalaris tuberosa,* perennial ryegrass, and Demeter fescue. Of the legumes, lucerne and various subterranean clovers have done well with differences in performance between localities.

In a comparison under limited grazing conditions Demeter fescue and white clover gave the greatest annual dry matter production and sheep liveweight gains per acre.

(*b*) *Pasture Ecology and Autecological Studies.*—Studies of the effect of winter burning on ungrazed native pastures have shown that the effect of time of burning, within the period June-September, had no effect on the yield of green forage in the following summer. However, the yield was reduced to about 50 per cent. of that from the unburned control plots. Where the pasture was burned during one winter, but not the next, the yield of green forage during the second summer after burning was the same as from the unburned control plots.

(*c*) *Grazing Management of Native Pastures*—A study has been made of ways of increasing production from native pastures by providing sheep with different portions of sown pasture for supplementary grazing. Liveweight gains of weaners, lambing percentages, and wool weights for all classes of sheep showed increases with increasing proportion of sown pasture.

(*d*) *Grazing Management of Sown Pasture.*—Studies have been commenced on the effect of time, frequency, and intensity of defoliation of the most promising pasture mixtures in order to determine methods of maximum utilization.

(*e*) *Improvement of Native Pastures.*—Grasses sown into native pasture previously surface seeded with clovers have demonstrated the superiority of ryegrasses for this form of pasture improvement compared with *Phalaris tuberosa,* tall fescue, and cocksfoot. None of the grasses established when sown directly into the native pasture without clover.

Preliminary results show that a better establishment with surface seeding of white clover is obtained if native pastures are burnt immediately prior to sowing.

(*f*) *Plant Nutrition Studies.*—A survey of the plant nutrient studies of soils of the New England region has continued. Studies of the response to both sulphur and phosphorus of all the main soil groups have been commenced. In an experiment on basaltic soil on which a natural pasture dominated by medic species had been shown to respond markedly to applications of sulphur, a study was made of the response of the pasture, under limited grazing conditions.

An examination of the sulphur status of basaltic soils in the Liverpool Plains and Northern Tablelands areas has shown that soil colour is correlated to sulphur deficiency. The general application of this relationship is being studied.

Renovation of *Phalaris tuberosa* pastures has been shown to result in an increased yield of *Phalaris* but a decreased yield of other species. This increased yield was due to greater availability of nitrogen and sulphur in the soil, which indicated accelerated breakdown of organic matter following renovation.

Various chemical methods of determining the soil sulphur that is available for plant growth have been investigated. Reducible sulphur, determined by digestion with a mixture of hydriodic acid, red phosphorus, and formic acid was found to be strongly correlated with plant growth. Water-soluble sulphur was also found to be significantly correlated with plant growth, but total sulphur was not.

(*g*) *Clover Nodulation.*—Attempts to confirm that the use of charcoal as an adsorbent would overcome the microbiological antagonism which had been shown to prevent nodulation of inoculated subterranean clover seed were unsuccessful. However, confirmation was obtained of previous results in which a high percentage of nodulated plants was obtained by the use of massive doses of inoculum, by the use of soil from an established stand of subterranean clover, and by the inoculation of seed from a problem area and sowing this in the row with the seed.

16. PASTURE INVESTIGATIONS AND AGRICULTURAL PHYSICS, DENILIQUIN.

(Division of Plant Industry.)

(*a*) *Agricultural Physics.*—Investigations are concerned with aspects of the energy and water balance of natural surfaces affecting plant growth.

(i) *The Propagation of Temperature Waves.*—Comparisons of temperature waves in soils of arid and humid regions have shown that under similar conditions of insolation the energy used for evaporation in humid areas is for the greater part transferred to the air as sensible heat in arid regions.

(ii) *Isothermal Soil Water Phenomena.*—The mechanism of soakage into soil of water made available at its surface is being investigated. Particular attention has been paid to the effects of initial soil moisture and depth of water over the soil.

(iii) *Simultaneous Transport of Heat and Moisture.*—Observed apparent vapour transfers in porous media under temperature gradients have been related to those theoretically predicted by taking into account the interaction between the vapour, liquid, and solid phases of the medium. Application of this work to the problem of evaporation from soil surfaces indicates that there are three stages in the desiccation of a given soil profile.

(iv) *Light and Pasture Growth.*—This work is concerned with optimum growth of pasture under limiting light conditions. Consideration of the carbon balance of the plant as influenced by both photosynthetic gains and respiratory losses has led to a quantitative theory of pasture growth which accounts for experimental observations. This work offers a means of assessing production potential and improving pasture management.

(v) *Seed and Root Aeration.*—The effect of seed size, respiration rate, depth of planting, and soil moisture on oxygen tension at the seed surface has been investigated.

(vi) *Advection.*—An investigation has been commenced into the theoretical and experimental aspects of advection as applied to the study of the energy and water balance of vegetation covering a portion of the ground as in a row crop or on arid area.

(*b*) *Ecology.* (i) *Phenology.*—The phenological survey of the Riverina Plain for the period 1949-1953 with special reference to *Danthonia caespitosa* has been completed. The data collected have been used to predict the type of vegetation that will develop after particular falls of rain. They could also be used to evaluate the chance of successfully establishing exotic species in the community.

(ii) *Weed Control in Rice Fields.*—Two summer-growing weeds, *Echinochloa crus-galli* (L.) Beauv. and *E. crus-pavonis* (H.B.K.) Schult., which reduce the yield of rice in the Tullakool district of south-western New South Wales, are not controlled by the usual irrigation techniques. Glass-house experiments have shown that four or five years of subterranean clover (*Trifolium subterraneum* L.) and Wimmera ryegrass (*Lolium rigidum* Gaud.) pasture on weedy rice soils reduce the seed content of the soil. Efficient drainage and irrigated sown pasture within the rice rotation appears to be a satisfactory method of control.

(*c*) *General Chemistry.* (i) *Soil Properties.*—An investigation to determine the chemical and physical properties which are important for plant growth, of soil type R from the Falkiner Memorial Field Station, has been commenced. Treatments to alter these properties are being studied.

(ii) *Organic Matter Survey.*—A survey of the organic matter present in pastures established for various periods has shown that—

1. There is no clear relationship between quantity of organic matter and age of pasture.
2. The C : N ratio (both in surface litter and in the 0.2½ in. layer of soil) is constant and independent of age.
3. Surface organic material shows a C: N ratio slightly higher than that in the soil.
4. The apparent density of the soil is directly proportional to the moisture content.
5. The rate of change of apparent density with moisture content appears to decrease with increasing organic matter content of the soil.

(*d*) *Agronomy.* (i) *Pasture Establishment.*—Experiments on the three soil types, loam, clay loam, and clay, representative of irrigated soils of the district, have shown poor pasture establishment to be caused by inability of the cotyledons or hypocotyl of germinated seeds to puncture the soil surface. It has been shown that keeping the soil moist without water-logging the soil partly overcomes this problem in the field. This work is continuing.

(ii) *Nutrition Studies.*—Experiments with Wimmera ryegrass and sudan grass on representative soils have shown that nitrogen is the principal factor limiting plant growth in the region. Once nitrogen requirements are satisfied, yield responses occur with the application of phosphorus and other elements, including sulphur. Responses to the addition of other elements in the presence of adequate phosphorus, nitrogen, sulphur, and iron are being investigated.

(iii) *Growth Studies.*—An investigation into the theory of pasture growth based on studies of subterranean clover has been initiated. It is planned to extend this work to grasses so that ideal sward management might be achieved.

(*e*) *Genetics.* (i) *Lucerne.*—A lucerne variety trial has been established with 15 varieties both under full irrigation and irrigation for establishment only. There are indications that an Indian and African and Hairy Peruvian strains are superior to Hunter River in the first year. Winter growth of the new strains is of particular interest.

(ii) *Subterranean Clover.*—Seed for testing has been collected from mixtures of strains and mixtures of hydrids of subterranean clover sown during 1955 at Deniliquin, Oaklands, Tooleybuc, and Euston.

Natural selection plots have been exposed to different irrigation treatments, watering being zero, autumn, spring, and both autumn and spring. Seed has been collected for later testing.

17. PASTURE INVESTIGATIONS, WESTERN AUSTRALIA.
(Division of Plant Industry.)

(*a*) *Studies on Perennial Grasses.* (i) Phalaris tuberosa.—An experiment to examine the effects of nitgrogen supply and extension of the growing season on four strains is proceeding. It now seems that the environment can be modified sufficiently to confer a competitive advantage on phalaris when growing in association with annuals. The influence of plant density and nitrogen supply on production and persistence is also being examined. A pot-culture trial to test the hypothesis that seedlings grown in saturated soil could exhibit poor resistance to desiccation has given a negative result.

(ii) Hyparrhenia hirta.—This grass is now being examined under continuous grazing conditions. A comprehensive collection of strains of the species, and of other species of the genus *Hyparrhenia*, is being made.

(iii) *Other Studies.*—The four grasses, *Hyparrhenia hirta, Ehrharta calycina, Phalaris tuberosa,* and *Oryzopsis miliacea,* each with and without fertilizer nitrogen, are being studied under intermittent heavy grazing at Perth and Kojonup. *Phalaris, Ehrharta,* and *Oryzopsis* have shown poor persistence at both sites, while *Hyparrhenia* has performed better at Perth than at Kojonup. There is evidence that low winter temperatures at the latter site are mainly responsible for the difference.

The breeding of a non-shedding strain of *Ehrharta calycina* by means of the polycross test is still proceeding.

An experiment has been commenced to study root development of three perennial grasses on five soil types.

(*b*) *Species and Strain Trials with Annuals.* (i) *Subterranean Clover.*—Seed yield trials of strains grown as spaced plants have shown that yields reach a peak with mid-season strains, and decline with late strains. It seems that internal water stress within the plant, arising mainly from low soil water availability, rather than from high atmospheric saturation deficit, is responsible for low seed yields of late strains.

Trials conducted at Perth and Kojonup on production in relation to strain maturity under sward conditions have shown that total production has no clear relation to maturity, whereas seed yield invariably declines with increasing maturity. Water supply becomes limiting very much earlier in swards than in spaced plants.

(ii) *Brome Grasses*.—Grazing trials on plots of the two mixtures, four species of *Bromus*, and eight strains of *B. mollis*, have been continued. Winter production of the mixture of *B. mollis* strains appeared inferior to the species mixture. The position was reversed for spring. Inflorescence counts in late spring showed that both *B. mollis and B. trinii* survived the first grazing year much better than *B. carinatus* and *B. catharticus*. The competitive effects of volunteer bromes, especially *B. rigidus* (ripgut brome), will be examined.

(*c*) *Plant Nutrition Studies*. (i) *Phosphate*.—Residual effects of superphosphate and rock phosphate on subterranean clover pasture are still under examination.

Work on the Western Australian blue lupin and subterranean clover in connexion with utilization of phosphate from rock phosphate has continued. Lupins have taken up more phosphate than has subterranean clover.

Work on a comparison between annual applications of superphosphate and a single initial application has been continued on two soil types using a subterranean clover pasture. Results have varied for each soil. Samples have been taken for phosphate fractionation, and residual phosphate measurements.

Contrasting soils used to examine the effects of time on fixation of added superphosphate showed that fixation occurred during the first three months of storage.

(ii) *Zinc*.—The effect of season on zinc response in subterranean clover over the past three seasons has been small. The various effects of phosphate supply on utilization of zinc are being investigated by the use of carrier-free radioactive ^{65}Zn.

(iii) *Sulphur*.—Responses to applied sulphur have been obtained on the three soil types examined at Kojonup. Applications of sulphate-S apparently prevent deficiency for three-four years, whilst cultivation of pastures relieves the deficiency temporarily.

(*d*) *Ecology of Annual-type Pastures*.—Long-term seasonal effects on botanical composition changes under grazing are continuing. Results show that seedlings of subterranean clover and silver grass have a lower relative survival than *Erodium*, cape-weed, and ripgut brome. Water supply during seedling establishment was shown to be one of the important determinants of botanical composition during any growing season.

(*e*) *Soil Fertility Investigations*.—Work on the relation between phosphate status of a subterranean clover pasture and the increase in total soil nitrogen has been continued. Although field trials have given negative results, pot culture trials have shown definite graded increases of soil nitrogen with increasing phosphate levels.

A study of the rate of increase in fertility during the first five years of a subterranean clover pasture is continuing.

Results from a trial, designed to examine the rate of build-up of soil nitrogen on different soil types, show that during the first two or three years the rate of increase in the surface 4 in. of soil has ranged from 50 to almost 200 lb. N/acre. The rate of increase is greatest on the soil of highest initial nitrogen level.

The influence of the grazing animal, and of mowing both with and without return of herbage, on soil nitrogen build-up, has been followed over a three-year period. Nitrogen gains have been substantial but treatment differences were very small.

18. Pasture Investigations, Queensland.

(Division of Plant Industry.)

(*a*) *Spear Grass Region*. (i) *Rodd's Bay*.—In the first two seasons sown pastures of *Chloris gayana, Paspalum commersonii*, and *P. plicatulum*, grown in simple mixtures with *Phaseolus lathyroides*, have carried more than three times as many stock as a spear grass pasture. Cattle on sown pastures were fit for market one year earlier than those on native spear grass because they showed liveweight gains in winter and spring when cattle on spear grass lost weight. Fertilizer was applied to the sown pastures but not to the native pasture.

Centrosema pubescens and *Crotalaria lanceolata* have grown well in small plots, while *Leucaena glauca* has potential value as a high-protein browse legume in spring and early summer.

Responses to potassium, calcium, and molybdenum were recorded in a field experiment on a prairie type soil at Rodd's Bay when adequate phosphorus was applied.

(ii) "*Brian Pastures*".—Work on the development of sown pastures on a granite soil at "Brian Pastures" has been concentrated on the nutrient factors limiting legume growth. *Phaseolus lathyroides*, Poona pea, and white clover were used as test species in experiments including all essential nutrient elements. Definite responses were obtained only to sulphur, phosphorus, and nitrogen, but there is evidence that molybdenum is also lacking.

However, legume growth remains poor when these four elements are supplied. Factors which complicate the deficiency problem, namely, high manganese content of *P. lathyroides* and Poona pea, and nematode attack on *P. lathyroides*, are now under investigation. Reliable assessment of sown grass and legume species on this soil cannot be made until the nutritional difficulties have been overcome.

(*b*) *Coastal Lowlands*.—Work at Beerwah is concentrated on selected species and mixtures following exploratory work on species and the soil nutrient status. Sheep and cattle are now being wholly maintained on sown pastures for the first time. The response of pasture mixtures to grazing, and fertilizer needs of pastures under grazing, will now be assessed.

Experiments to observe and record the compatibility and competition of grasses and legumes under grazing in simple and more complex mixtures have been commenced at Beerwah and at the Pasture Experiment Station, Samford.

Particular attention has been devoted to an assessment of white clover strains. This legume has shown notable persistence and ability to spread on low humic gley soils; a recently introduced Italian strain has grown particularly well and has seeded freely. Root distribution of white clover in response to lime and phosphatic fertilizer placement is being observed. Ground-water level fluctuations important in this environment are being recorded on an automatic recorder recently installed.

(*c*) *Brigalow Region*.—The yields and persistence under grazing of introduced grasses and legumes established in swards have been recorded at Taroom and Goondiwindi. At Taroom selected strains of Rhodes grass and *Panicum coloratum* have grown well in their second year. Strains of *Cenchrus ciliaris* and *Panicum maximum* and species of *Digitaria* and *Urochloa* have given disappointing results following satisfactory growth in the first season. *Paspalum* species, except *P. pauciciliatum*, have failed following poor establishment. Lucerne is the most outstanding legume and barrel medic is also promising. A selection and breeding programme has been commenced with lucerne. *Phaseolus lathyroides* made excellent growth and seeded heavily in the year of establishment but has regenerated poorly. Large numbers of seeds germinated in the second year, but the plants failed to survive the seedling stage.

Selected pasture mixtures in 1-acre blocks gave yields ranging from 2 to 6 tons of dry matter per acre from the first year's growth. In experiments to provide high-protein ley pastures for use in the winter months, high dry matter yields were obtained from *Vicia villosa* and *V. pannonica.* Variety trials to evaluate the grain yields of *Phaseolus* pulse species as sources of protein concentrate have been initiated.

At Goondiwindi Prebies strain of *Bromus catharticus* has proved a valuable component with lucerne and barrel medic in winter producing ley pastures. The evaluation of introduced summer growing grasses has begun at this centre.

Plant nutrition studies on brigalow soils, and other major soil types associated with brigalow country, have shown that the majority of soils are deficient in phosphate while some soils also respond to sulphur and molybdenum.

(*d*) *Lockyer Valley.*—Herbage production of *Paspalum commersonii* on black soils at Lawes was at its highest where a dressing of ammonium sulphate was applied and sheep grazing the pasture had access to lucerne. The effect of transfer of nitrogen by grazing stock from lucerne to unfertilized *P. commersonii* became evident in the second season.

(*e*) *Ecology.*—A rainfall map of south-eastern Queensland and a study of the variability of soil phosphate in relation to the distribution of natural vegetation in parts of the coastal lowlands have been completed.

Field work for geological study of an area covering the boundary of the coastal lowlands has been completed, and a study is being made of the mineralogical changes that occur when sedimentary rocks of this region weather to form the existing soils.

A reconnaissance has been made of the submountainous country which will be covered in the ecological study of the spear grass region. This lies between the Great Divide and the coastal lowlands, with a southern boundary running from the coastal lowlands north of Brisbane, via the Brisbane Valley to the point where the Great Divide joins the Darling Downs; the northern boundary follows the Dawson Valley to Mount Morgan.

(*f*) *Legume Bacteriology.* (i) *Accumulation and Comparative Testing of Strains of* Rhizobium.—The collection of proven strains of *Rhizobium* now numbers over 500. During the year 438 cultures were supplied for use in glass-house and field experiments.

Tests of nitrogen-fixing ability were made in vermiculite-filled Leonard jars on 109 strains of *Rhizobium.* Yields and nitrogen content of dry matter were measured and the strains compared on the basis of mg of nitrogen fixed per plant. The tests were carried out on three tropical species, *Leucaena glauca, Stylosanthes gracilis,* and *Stylosanthes sundaica,* and three temperate clover species, *Trifolium fragiferum, T. incarnatum,* and *T. alexandrinum. Stylosanthes* species and *Leucaena glauca* proved to be fairly strain specific.

(ii) *The Relationship of* Rhizobium *to Tropical Legumes.*—Work has been concentrated on calcium nutrition and a number of strains have been grown in clay suspensions with adjusted calcium levels. Strains from *Trifolium* and *Medicago* species appear to be highly sensitive to calcium supply and make no significant growth until a relatively high degree of saturation is reached, but strains from *Glycine, Vigna,* and *Acacia* (the " cowpea " group) will grow readily at low levels of calcium.

This indicates that *Rhizobium* may be divided into two groups according to calcium requirement, the " cowpea " type of *Rhizobium* associated with the majority of legumes requiring only a trace of calcium, but the type associated with Trifolieae and Vicieae depending on calcium in substantial quantity.

(*g*) *Feeding Value of Pasture Species.*—Nutritional studies have been continued using a number of subtropical pasture species. Caged crossbred sheep have been used to determine digestibility, intake, and nitrogen balance.

(i) *Subtropical Grasses.*—A comparative study of the four grasses *Paspalum commersonii, Panicum maximum* (var. *trichoglume*), *Cenchrus ciliaris,* and *Chloris gayana* is being made. The order of palatability to sheep as measured by dry matter intake per head per day was (1) *C. ciliaris,* (2) *P. maximum* and *C. gayana* about equal, (3) *P. commersonii.* Differences between these species in dry matter digestibility are not great. The results have stressed the importance of winter greenness and succulence in subtropical pasture species in relation to intake of feed. *Paspalum plicatulum* was consumed in larger quantity and was more digestible than *Paspalum notatum.*

(ii) *Supplementary Feeding.*—A study was made of the effect of supplementing poor-quality *Paspalum commersonii* roughage with green lucerne at rates of 600 and 1200 g per day. The sheep consumed more roughage only at the lower rate of lucerne feeding; at the higher rate the digestibility and intake of roughage was depressed.

(iii) *Indirect Measurement of Digestibility and Intake.*—Correlations of dry matter intake with total faecal nitrogen for a number of subtropical pasture grasses have shown that species can be grouped according to this relationship. These findings may be used to measure the intake of free grazing animals on monospecific swards, or on mixed swards of species from the same group, simply by recording total faecal nitrogen.

Experiments using the chromogen technique to measure the intake of the grazing animal have been completed. The percentage recoveries of chromogen were so variable that the technique, as at present employed, appears unsuitable for pasture intake estimates under local conditions.

(*h*) *Plant Breeding and Genetics.*—Breeding experiments on grass and legume species favoured for use in sown pastures in the subtropical zone of Queensland have continued.

A study of plants covering the available strains of *Indigofera endecaphylla* showed a range of total aliphatic nitro-compound content between strains but little intrastrain variation. A crossing technique has been devised and a number of crosses made within the species. Interspecific crosses between *Indigofera* species have not been successful. Seed of *I. endecaphylla* has been treated with X-rays and thermal neutrons with the object of obtaining a non-toxic mutant.

The breeding system and intrastrain variation in *Leucaena glauca* have been studied, and a crossing technique has been developed. Self-pollination results in a high degree of uniformity within strains.

Because anthesis occurs in the closed bud of *Phaseolus lathyroides* at the commencement of bud expansion, the species is closely self-pollinating and a search for variants has proved unsuccessful. Crosses between other *Phaseolus* species and *P. lathyroides* are being attempted. The characters sought are perenniality, frost tolerance, nematode resistance, and resistance to Phaseolus virus 2.

An examination of large numbers of seedlings of *Sorghum* species, mainly *Sorghum almum,* revealed a few plants low enough in cyanogenetic glucosides to be used in breeding for low toxicity.

The breeding systems and strain variations in the grasses *Setaria sphacelata* and *Chloris gayana* are being investigated. The species are self-incompatible and normally cross-pollinating. The characters present in populations of the different strains are being examined under grazing. Superior selections will be intercrossed and populations developed for further selection of desirable types in a number of localities.

Further work on the problem of apomixis in *Paspalum* and *Panicum* has indicated a degree of fertility in some species.

(*i*) *Plant Chemistry.* (i) Indigofera endecaphylla.—A new colorimetric method for the determination of β-nitropropionic acid in plants has been critically examined. Results, compared with those from the chromatographic method developed in this Laboratory, were consistently too high. This indicates the presence of substances which interfere with the colorimetric procedure.

Alcohol-soluble nitrogen compounds from an ethanol extract of *I. endecaphylla* were fractionated and combined neutral and acidic fractions examined for nitro-compounds by catalytically reducing these to the amino compounds. Qualitative two-directional chromatographic analysis showed a β-alanine content in agreement with the β-nitropropionic acid content of the samples as determined chromatographically. Work on the identification of other aliphatic nitro-compounds present in *I. endecaphylla* is proceeding.

(ii) Leucaena glauca.—The substance occurring in *L. glauca* previously shown to be chromatographically identical with 5-hydroxypipecolic acid has been isolated and its identity confirmed by direct comparison with a sample of the isolate from *Baikiaea plurijuga.* 5-hydroxypipecoli acid has been synthesized and the resulting disastereoisomers have been separated. One of these is chromatographically identical with the natural isomer which has a configuration analogous to that hydroxy-L-proline.

(*j*) *Plant Nutrition.* (i) *Nutrient Status of Soils.*—Herbage yields from pasture experiments at Beerwah have been maintained at levels of up to 3 tons/acre of dry matter from a single harvest. Fertilizer applications were 2 cwt. of superphosphate per acre and up to 3½ cwt. per acre of potassium chloride. These pastures have been mown and the equivalent of 1½ cwt. each of superphosphate and potassium chloride removed annually in the crop. The pasture will now be managed under grazing, and a reduction in fertilizer requirements through the cyclic transfer of nutrients is anticipated.

(ii) *Nutrition of Pasture Species.*—The relative growth response of a number of pasture legume and grass species of potential value in subtropical Queensland has been ascertained in pot experiments for the elements phosphorus, calcium, and copper. Copper and calcium growth responses have also been measured using water culture, and the foliar symptoms of copper and calcium deficiency have been recorded. A chemical analysis of the plant material is being made.

(iii) *Rock Phosphate Utilization by Pasture Legumes.*—Tropical legumes have shown a general superiority over temperate legumes in utilizing rock phosphate. Among the temperate legumes *Medicago sativa* and *M. tribuloides* responded well to rock phosphate, but the response of *Trifolium repens, T. fragiferum, T. incarnatum,* and *T. alexandrinum* was negligible.

(iv) *Nitrogen Fixation by Pasture Legumes.*—Productivity of pasture grasses in Queensland is severely restricted by a shortage of available soil nitrogen. This deficiency may be overcome by the use of pasture legumes. Experiments to investigate the nitrogen-fixing efficiency of a number of these have begun. Rate of fixation of atmospheric nitrogen is being related to growth and development under glass-house conditions, and a study of the factors modifying the usefulness of these plants under field conditions is being made. The influence of soil moisture stress on the growth and nitrogen nutrition of *Phaseolus lathyroides* is receiving particular attention.

(*k*) *Plant Physiology.*—Studies of the effect of potassium and sulphur starvation on the nitrogen metabolism of plants have been concentrated on the metabolism of amino acids and related substances.

The diamine putrescine known to occur in potassium-starved barley is also found in smaller amounts in potassium-starved white clover, red clover, subterranean clover, and lucerne, and its maximum accumulation coincides with the appearance of leaf symptoms of potassium deficiency. Similar symptoms developed in two days when putrescine was administered to normal red clover plants. Radioactive tracer techniques are being used to investigate the pathways of putrescine metabolism. Other work is proceeding on some aspects of cation and anion uptake in potassium-deficient plants and their possible relation to putrescine accumulation.

Accumulation of free amino acids in sulphur deficiency may be directly concerned with sulphur metabolism. Some amino acids, particularly arginine, have been shown to be greatly increased by the deficiency. Others such as glutamic acid are considerably reduced. Citrulline and ornithine were found in sulphur-deficient flax where arginine is a prominent amino acid. The presence of these substances in association with arginine suggests that arginine may be formed from ornithine via citrulline.

Carbon-marked ornithine, citrulline, and arginine have been fed experimentally to barley and white clover plants, and it has been shown that arginine is formed from L-citrulline-^{14}C, and that plants receiving *dl*-ornithine-2-^{14}C can convert it to citrulline and arginine.

19. BIOPHYSICAL RESEARCH.

(University of Tasmania.)

The Organization is supporting biophysics research in the University of Tasmania by providing finance for a post-graduate studentship and a grant for general laboratory purposes. In March, Mr. I. S. Jenkinson, honours graduate in Physics from the University of Queensland, was awarded the studentship.

The following investigations are being undertaken in the Biophysics Laboratory:—

(*a*) Microelectrode techniques have been developed in order to measure potential differences between points in the cytoplasm of large plant cells such as *Nitella and Chara.* Changes in potential associated with the starting and stopping of cytoplasmic streaming are being investigated.

(*b*) Further studies are being made of the steady electric field pattern around plant roots growing in solutions of various ionic compositions and concentrations.

(*c*) The nature of transient changes in the electric field of bean roots following stimulation is being studied. It is hoped to postulate a satisfactory mechanism for these changes, and for the spontaneous electric oscillations occasionally generated by the root.

(*d*) The study of regeneration of adventitious buds in the epidermis of decapitated flax seedlings following wounding by cutting is continuing. In particular the factors governing the vascular connexion between the regenerating apex and the stele are being considered.

(*e*) The effect of the passage of electric currents along excised sections of flax hypercotyl on the formation and polarity of development of adventitious buds in the epidermis is being studied.

20. FODDER CONSERVATION.

(Plant Fibre Section.)

(*a*) *Haymaking.* (i) *Field Trials.*—Experiments have been continued at the field Station at Cobram on the making of lucerne hay. The main object of the trials is to determine the effect of time and method of raking on the characteristics of the windrows formed and their rate of drying, the mechanical and other losses involved, and the change in chemical composition of the crop. Early trials of this nature were not entirely satisfactory, largely on account of sampling difficulties, but this trouble now appears to have been overcome by the development of equipment for lifting whole swaths and windrows for periodical weighing.

An investigation has been made of the pick-up of moisture by baled hay exposed to rain.

(ii) *Chemical Investigations.*—Suitable methods of analysis are being developed for the examination of the changes associated with the conservation and storage of fodder both as hay and silage. Particular attention is being given to the carbohydrate and nitrogenous constituents, although considerable work has also been done on methods of determining the lipids. One of the main problems associated with analyses of the above nature is the determination of moisture content; various methods of drying samples, including freeze-drying, are being studied.

One chemical investigation in hand is concerned with the effect of maturity of fodder crops such as ryegrass and clover on their carbohydrate content. Another study is of the effect of moisture content and temperature during storage on the chemical composition of hay of such crops; from preliminary investigations it appears that appreciable changes may be expected except at very low temperatures.

(iii) *Physical Investigations.*—Studies have been continued of the drying characteristics of pasture plants including the differential drying of leaves and stems. Not only do the stems of most plants have a higher initial moisture content than the leaves but they dry more slowly; this increases the hazards associated with attempts to bale hay before the leaves have become brittle. Investigations have also been made of the effect of drying conditions on the loss of dry matter by continual respiratory and enzymic actions after the plant has been cut. These losses are often quite appreciable, and their extent and nature are of considerable interest.

Moisture equilibrium curves have been established for freshly mown material of several haymaking species harvested at various stages of maturity and for similar material cured under different conditions. Information of this nature is frequently required in connexion with haymaking experiments.

Mechanical losses associated with haymaking and often amounting to as much as 25 per cent. are largely the result of portions of the plant, especially the leaves, becoming very fragile during drying. An extensive study is being made of the effect of various growing and curing conditions on the fragility of pasture material.

(*b*) *Ensilage.* (i) *Laboratory Trials.*—Experiments have been continued with small laboratory silos ensiling ryegrass, clover, and lucerne. To eliminate losses associated with effluent production, the effects have been investigated of either wilting the crop before ensiling or of adding moisture absorbing materials such as chaff or ground wheat; other experiments have been concerned with the use of molasses and sodium metabisulphite as additives. A preliminary investigation has been made of the use of plastic containers for silage making.

(ii) *Microbiology of Ensilage.*—The characterization of strains of lactic acid producing bacteria isolated from various laboratory ensilage experiments is proceeding, together with the study of their nutritional requirements. A striking feature of ensilage is the rapid hydrolysis of the protein due to autolytic processes in the plant. As this represents the first step in a series of changes which lead to loss of nitrogen, the factors affecting this breakdown of protein are being examined, bearing in mind the possible contribution which the soluble nitrogen may make to the development of the lactic acid bacteria. Studies are also being made of the redistribution of nitrogen during wilting prior to ensilage.

21. Agricultural Engineering.

(Plant Fibre Section.)

Investigations have been continued to study the functions of the mowing machine with respect to the cutting force, the stubble pattern, and the behaviour of the crop during cutting. An attempt was made to evaluate and fix the direction of the cutting force in a mower by means of appropriately located strain gauges and oscilloscope equipment; however, this was unsuccessful because the apparatus was incapable of passing signals at the necessary frequency. Improved equipment is now being developed. A rapid and easy method of drawing the theoretical stubble pattern has been devised, and comparisons between actual and theoretical patterns are being made. The behaviour of the crop during cutting has been examined by stereoscopic high-speed photography.

A complementary study to that outlined above is concerned with the mechanical properties of plants, and measurements have been made of shear and bending strength of three common forage crops.

IV. IRRIGATION.

1. General.

The production of crops under irrigation requires specialized techniques, and the continued application of water to the soil can result in problems not encountered in dry-land agriculture. The deterioration of land under irrigation is a world problem of great magnitude.

For the study of ways in which irrigated land can be made to keep its fertility, and waterlogged land can be reclaimed, the Organization has two Irrigation Research Stations: the Commonwealth Research Station (Murray Irrigation Areas) at Merbein, Victoria, on the Murray River, and the Irrigation Research Station (Murrumbidgee Irrigation Areas) at Griffith, New South Wales. The work of these two stations is reported in this Chapter.

Research into soils and their behaviour under irrigation has been carried out at both Merbein and Griffith in close co-operation with the Division of Soils (*see* Chapter II.).

Studies of irrigated pastures are carried out at Deniliquin, New South Wales, by the Division of Plant Industry (*see* Chapter III., Section 16), and other investigations of irrigation techniques for northern tropical areas are performed by the Land Research and Regional Survey Division at the Kimberley Research Station, near Wyndham, Western Australia (*see* Chapter XI., Section 3). Work on dried vine fruits in progress at the Commonwealth Research Station, Merbein, Victoria, is reported in Chapter XIII, Section 13.

Irrigation Research Stations.—Excessive rainfall during 1956 led to serious flood problems in many of the irrigation districts of south-eastern Australia and to heavy losses of plantings. In the Murrumbidgee Irrigation Areas, while there were heavy losses of peaches and citrus in undrained areas, there were actually none in areas which had been tile drained. Such experiences highlight the urgent need for protection of irrigation areas by means of adequate surface drainage and for much more detailed knowledge of the internal drainage characteristics of soils and understrata, both in existing and proposed irrigation lands.

In the spring of 1956, a discussion group on groundwater hydrology was held at Merbein Station. This, the first of its kind, was attended by 39 officers from eighteen Australian authorities concerned with ground-water.

The Water Conservation and Irrigation Commission of New South Wales continues to make an annual contribution to funds of the Griffith Station. In the Murrumbidgee Irrigation Areas and elsewhere, co-operative work is done with officers of the Commission, epecially on groundwater problems.

The Commonwealth Dried Fruits Control Board, the Mildura Packers' Association, Co-operated Dried Fruits Sales Pty. Ltd., and the Nyah-Woorinen Enquiry Committee continue as contributors to funds of the Merbein Station.

On behalf of the Department of External Affairs by arrangement with the Organization, the Senior Officer-in-Charge attended a training centre and study tour on irrigation and drainage in the Union of Soviet Socialist Republics.

2. MERBEIN.

(*a*) *Irrigation, Soil Preservation, and Soil Reclamation.*—Investigations have proceeded in the Renmark district of South Australia, the Sunraysia and Swan Hill districts of Victoria, and the Wakool area of New South Wales.

Observations in piezometers and auger holes were made to assess changes in ground-water conditions caused in the Renmark district by the record flood of the River Murray. This was part of a co-operative investigation with the South Australian Department of Agriculture of damage to plantings and of the associated soil conditions. Information obtained was available to the Renmark Irrigation Trust to guide their irrigation and drainage programme.

Tests of a screened bore on the farm of Swan Hill Irrigators' Research Committee revealed that the overburden had a low hydraulic conductivity, making it doubtful that the land could be drained by pumping from the sand bed at 20 feet deep. Further determinations of hydraulic conductivity in other parts of the farm have confirmed the presence of areas likely to give economic response to tile drainage at 5 feet deep or more, but an area suitable in size and other respects for experiment has not yet been located.

The relation between flow from tile drains in Mallee soils, and hydraulic conductivity determined by the piezometer and auger hole methods, has been studied. Hydraulic conductivity decreased with depth, partly owing to increasing clay content, but also to presence of a very sticky, easily dispersed clay. Work has been hampered by apparent decrease in hydraulic conductivity in time during a determination, apparently owing to entrapped air. Apart from this, discrepancies have been noted between observed and calculated drain flows, and will be investigated further.

Piezometers and test wells have been installed in pairs to provide a record of ground-water conditions at the plot areas of the Wakool Land Use Committee, including the area of pasture being established on Moragh loam in the developing Deniboota Irrigation District.

(*b*) *Land Use.*—A soil survey of 260 acres which was carried out during the year for a small group of growers at Trentham Cliffs, New South Wales, indicated that the area is unsuitable for development for horticulture at the present time.

(*c*) *Horticulture.*—Microscopical examination of dormant sultana buds in May, 1956, showed 43 per cent. to be fruitful compared with a ten-year average of 50 per cent. A potential crop of 30-32 cwt. per acre was forecast for the Sunraysia district. Growers were advised to prune to a greater number of buds than usual. On ten survey sites an average of 25 per cent. more buds were left and the 1957 harvest averaged 33 cwt. per acre.

A potential crop of 36 cwt. per acre is forecast for the 1958 harvest in Sunraysia from a figure of 59 per cent. fruitful buds in May, 1957.

Vines which had been completely inundated at Renmark during the River Murray floods of spring, 1956, burst up to ten weeks later than normal. Fruitfulness was in general lower than normal, very weak canes being almost entirely barren.

Zante currant vines sprayed with 2,4-D in lieu of cincturing to promote fruit setting gave better-quality fruit in the 1957 harvest than vines sprayed with PCPA, although yields were the same. In a preliminary trial 2,3,4-T showed promise, without any formative effects on vine growth.

The Ohanez variety was heavily infected within the dormant buds by the bud strain of the mite *Eriophyes vitis* which apparently damages the bunches, causing a proportion of them to disappear after bud burst.

The weed "hard-head" (*Centaurea picris*) has been successfully controlled by C.M.U. on areas not used for horticulture.

Yield of sultanas has been significantly related to hours of spring sunshine seventeen months and 29 months before harvest. A regression equation has been determined for each of the districts Mildura, Merbein, Red Cliffs, and Coomealla. A significant general decline of about 25 per cent. in yield over the last seventeen years in Coomealla may be due to an aging in the vines in this settlement, which is not yet old enough to have reached the stability of the older settlements.

A further relation is being developed between sultana yield and mid-winter temperatures seven months before harvest.

Evapotranspiration from sultana plots in summer amounted to about 2½ inches of water in the ten days after irrigation, then dropped to about ¾ inch per week, which is probably close to the transpiration figure. The difference represents loss by direct evaporation from a surface still moist from irrigation. Direct determinations of soil moisture were used, together with an estimate of moisture movement down from or up into the root zone derived from changes in soil chlorides.

Daily transpiration from these vines was also estimated by using H. L. Penman's formula, modified in the light of the experimental results above. For December, January, and February, daily transpiration again averaged about 0.10 inch, with a range from 0.052 to 0.142 inch per day in the 1955-56 season.

(*d*) *Plant Nutrients.*—The hypothesis of winter uptake of nutrients, in particular of nitrogen, and of July as a critical period in fruit bud development, is supported by results from winter applications of sulphate of ammonia in two trials. Sultana yields were increased significantly by late June/early July applications, but not by applications later in the winter; early September applications also increased yields significantly. In trials where weeds are controlled by sprays without cultivation, creosote gave yield increases for the second time in three years, where it had been applied in mid-May or mid-June. This suggests a soil sterilizing effect which increases soil nitrate.

Intensive investigations of the nutrient requirements of the sultana vine in the field continue to provide variable results. It is obvious that, in general, and under a variety of cultural practices, sultana vines are provided with a sufficiency of the principal nutrients. Responses to application of sulphate of ammonia and superphosphate have occurred in some trials but the yield increases, although significant, have hardly been worth while economically.

(*e*) *Vegetables.*—Tomato hybrids, bred by the Station and the Division of Plant Industry, resistant to root-knot nematodes and fusarium wilt fungus, and with highly desirable agronomic features, are under selection and field test for large-scale field production in the Murray and Murrumbidgee Irrigation regions. These hybrids would also be suitable for the Goulburn Valley.

Glass-house tomatoes are being bred for selection particularly for resistance to root-knot nematodes, fusarium wilt, and leaf mould. The glass-house trials are being extended to the Mid Murray district.

(*f*) *Nematology.*—In the sixth year of a field management trial at Red Cliffs for control of root-knot nematodes in tomato, all plots were planted to the susceptible variety Pan America. Previous history of sixteen treatments included combinations of fallow, barley cover crop, *Crotalaria*, susceptible and resistant tomatoes, and peanuts. Yields in 1956 reflect the value of resistant hybrids grown in previous years, and of crop rotation, particularly of *Crotalaria.*

Soil fumigation trials using a fusarium-resistant, nematode-susceptible tomato showed that the standard soil fumigant used locally (E.D.B.) is as effective as " Nemagon " (1,2-dibromo-3-chloropropane), while both are much superior to " Vapam " (sodium *N*-methyl dithiocarbamate) at concentrations used.

Counts of root-knot larvae in soil samples made at intervals throughout the year have revealed summer maxima of 13,800 and winter minima of 300 larvae per lb. of soil. It is concluded from these studies and from the Red Cliffs tomato trial that it is the eggs rather than the larvae in the soil which are important in commencing infections.

Three new species of tylench were discovered in uncleared Mallee soil near Hattah—a *Hoplolaimus* and two species of *Radopholus*. This is the first time the latter genus has been noted in Victoria. One resembles closely *R. similis,* a serious plant parasite.

Seeds of *Vitis rotundifolia,* a resistant species which is incompatible with *V. vinifera,* have been imported for plant breeding studies.

Initial observations on the structure and chemical composition of the cuticle and egg sac of *Meloidogyne* sp. indicate that the egg sac is a tanned protein and that the enzyme polyphenol oxidase is present.

The response of second stage larvae of *Meloidogyne javanica* to root secretions and chemicals is being studied, and an apparatus has been designed which facilitates observations of larval migration.

Histological studies to reveal size and structural differences of glands of second stage larvae of *M. javanica* before, during, and after moulting have been commenced in an endeavour to supply further evidence of a recent endocrine hypothesis for the control of nematode ecdysis.

(*g*) *Dried Vine Fruits.*—The work of the Commonwealth Research Station, Merbein, on dried vine fruits is reported in Chapter XIII., Section 13.

3. GRIFFITH.

(*a*) *Soil Chemistry.*—The factorial citrus experiment on Farm 466 is being used for soil as well as horticultural studies. This experiment involves Valencias and Washington Navels each on two rootstocks with four cultural and four nitrogen treatments. The trees were planted in the field in 1941 and the treatments commenced in 1947.

Possible changes in soil inorganic composition, organic matter composition, texture, or mineralogy, due to fertilizer and irrigation treatments, are being studied on this soil, a Hanwood sandy loam. The surface layer of selected plots where there is no cultivation and weeds are controlled by oil spray is under study.

Sulphate of ammonia, applied in increasing amounts, caused a progressive drop in pH of the surface 4 inches of soil. Similar trends were found for exchangeable hydrogen. Ammonium was present in greater quantities in the tilled than in the non-tilled plots. Chlorine levels were generally low; application of sulphate of ammonia reduced the amount of chlorine present in the top foot of soil.

(*b*) *Horticulture.*—Nitrogen appears to have had only a limited beneficial effect on fruit yield and growth on the Farm 466 citrus trial, but a rather adverse effect on fruit quality. This was found to be associated with phosphorus deficiency, and treatments were modified so that since 1955 superphosphate totalling 12 cwt. per acre has been applied to all cultural treatments. Fruit quality in grass sod and bare soil treatments, previously low, has improved spectacularly. The depressing effects of nitrogen fertilization, which also existed before the applications of superphosphate, are still very pronounced. In the tilled treatments, an improvement in fruit quality occurred only at the lowest nitrogen levels. At the moment, fruit quality is about the same in all cultural treatments which have the same nitrogen level.

Analysis for phosphorus in spring cycle leaves, sampled in February, 1957, indicate that the recovery in fruit quality was caused by a marked improvement in the phosphorus status of the trees. Where fruit quality was poorest and phosphorus status lowest in 1954—in the grass sod treatment—phosphorus content of leaves increased by 70 per cent. by 1957. In the other plots, phosphorus content of leaves was raised also over this period, but not to the same extent. An inverse relationship between phosphorus content of leaves and level of nitrogen supply which existed, prior to the application of superphosphate, only in the no-tillage plots, now exists in all cultural treatments. The depression in leaf phosphorus content is still most pronounced in the no-tillage treatments. The apparent interference by nitrogen with phosphorus nutrition did not appear, from glass-house trials, to be a " dilution " effect. It has been observed that soil pH decreases steeply with increasing applications of sulphate of ammonia in this trial, and a glass-house trial using surface soils from these plots confirmed that dry matter production of lemon cuttings was adversely affected by increasing levels of nitrogen.

The four nitrogen treatments are now applied with and without graduated applications of lime to evaluate the effect of the soil acidifications caused by continuous use of ammonium sulphate.

(*c*) *Plant Physiology.* (i) *Plant/Water Relations.*—Studies have been continued of the effects of a brief period of water shortage on plant growth.

The development of moisture stress effects has been followed from a similar viewpoint to that previously reported, but in greater detail. Day-to-day changes in nutrient components are being obtained from analyses. Trends in nucleic acid content and fractionation of phosphorus compounds have been studied.

These detailed studies have been moved now from the glass-house to a controlled-environment room where it has been found that growth rates in the test plant (tomato) under artificial lights are as good as if not better than in the glass-house with seedlings of comparable age. Work is now being concentrated on assessing the nature of the " primary lesion " in metabolism. This is complicated, as so many aspects of metabolism are impaired by moisture shortage. Accordingly, an effort has been made to separate phosphorus compounds on the basis of molecular size, or the degree of organization into functional molecules from the metabolic viewpoint.

The response of various laminae and of the stem and petioles have been considered under both continuous and interrupted lighting. In the laminae at incipient moisture stress, the changes are greatest in the lower leaves. There is little effect on acid-insoluble fractions. However, there is a real effect on inorganic phosphorus as such and on acid-soluble organic phosphorus compounds.

Later work, which is being continued at the Faculty of Agriculture, Oxford, England, involves use of the lupin, as well as the tomato, as the test plant. Microscopic dissection has been used to study development of primordia and volume of the apex at several stages both during water shortage and upon rewatering. The changes in the pattern of apical development are being compared with effects on basal leaves.

(ii) *Salt Intake.*—The effect of sodium chloride in water cultures on morphology and histology of *Atriplex hastata*, a saltbush, has been studied. The salt produces an accelerated rate of leaf thickening and extends the ontogenetic period. Numbers of epidermal cells per leaf decreased progressively with increasing concentrations of sodium chloride. The salt-induced thickening rate is looked upon as a process superimposed on a rather similar light- and moisture-sensitive process. The high salt cultures (up to 0.6 molar), which greatly reduced growth, apparently did not reduce turgor pressures necessary for succulence.

(iii) *Plant Nutrition.*—Peach and apricot leaf samples from commercial orchards of the Griffith and Leeton areas are being analysed for mineral nutrients with the aim of disclosing possible nutritional effects on growth and yields. Leaf analyses on peaches, apricots, and prunes have indicated that potassium levels are usually low in those trees adversely affected by the flood rains and waterlogging of 1956, and this effect is most marked in apricots. The lowered potassium levels are sometimes associated with small but not equivalent increases in sodium levels.

Washington Navel cuttings grown in the glass-house were exposed to a brief period of high salinity, using calcium, magnesium, and potassium chlorides. Cation analysis showed that while potassium is highest in actively growing parts, sodium is evenly distributed throughout the plant. Calcium and potassium increased during the salt treatment but the increased cation uptake fell well short of the uptake of chlorine. There was some evidence that potassium mobility may be restricted in leaves high in chlorine.

Two varieties of barley, one more sensitive to salt than the other, were grown in pots in the glass-house. After being established, the plants were treated for eight days with sodium chloride added to the nutrient solution. No change occurred in relative growth rate during salt treatment, but after salt was removed the relative growth rate was significantly lower in the salt-sensitive variety than in the other, while it was lower in both varieties than controls. Upon recovery from the treatment, relative growth rate of the treated plants was usually higher than for untreated plants. This result was similar to that observed for plants subjected to a brief period of water shortage, but it is considered likely that factors other than physiological drought are involved.

Symptoms in barley plants from salt applications are more severe in summer than in winter—plants treated with high levels of calcium chloride die off after three to four days of treatment in summer while they appear normal after a similar period in winter.

(*d*) *Land Drainage.*—In co-operation with the Water Conservation and Irrigation Commission, an investigation of the physical behaviour of tile drain installations on horticultural farms of the Murrumbidgee Irrigation Area is now nearing completion. Advantage was taken of the increasing number of installations to double the number studied during the year. Apart from some complete farm drainage systems, a dozen single laterals were studied in detail. The extremely wet season of 1956 gave the opportunity to study their behaviour under rather critical conditions, and it is therefore not necessary to extend the observations over another season. The information obtained will be compared with results from theoretical approaches and used to evaluate the adaptability of field conditions to the simplified flow-geometry assumed in drain-spacing formulae.

Another project with the Water Conservation and Irrigation Commission is a laboratory study of the relationship between hydraulic conductivity and drainable porosity. Undisturbed core samples were drained under low tensions to evaluate the usefulness of formulae based on non-steady–state conditions, which are claimed by some to be appropriate in irrigation areas.

Variations in soil anisotropy within one soil type appear to be too great for the piezometer method to be readily adaptable to routine work, despite the fact that measurements with this method are relatively simple. The variations found cannot always be attributed to readily observable causes. Similar results have been obtained overseas, which suggests that the condition is a rule rather than an exceptional case. The problem remaining to be solved therefore appears to be how to replace a heterogeneous anisotropic medium by a homogeneous anisotropic medium with the same overall anisotropy.

V. ANIMAL HEALTH AND PRODUCTION.

1. GENERAL.

The importance of live-stock production to the national economy cannot be too strongly stressed, and any increase in knowledge in this field ultimately affects every member of the Australian community.

The Division of Animal Health and Production is responsible within the framework of the Organization's programme of research into problems of the animal industries, for investigations concerned with animal health and reproduction, and with general animal husbandry.

The head-quarters of the Division is located in Melbourne, but its activities are spread throughout the Commonwealth. Reports on the work in progress are presented in this Chapter and in Chapters VII. and VIII.

The work of the Division of Biochemistry and General Nutrition on nutritional problems is reported in Chapter VI. Section 12 of this chapter deals with investigations of the Animal Genetics Section other than those on sheep and cattle which are included respectively in Chapter VII., Section 15 and Chapter VIII., Section 9.

Division of Animal Health and Production.—This Division is necessarily a large and scattered one because of the nature and scope of its work. Since a Committee of Management, comprising the Chief, Assistant Chiefs, and Divisional Secretary, was established in 1954, an increasing measure of decentralization has been introduced in divisional administration, with considerable advantage. The broader questions of research and administrative policy are dealt with from time to time by the Committee of Management and are discussed at an annual meeting of all officers-in-charge. The implementation of the research programme is in the hands of the officers-in-charge and their local colleagues, with the advice in some instances of a Technical Committee. This system is working well and is paving the way towards the organization of the Division into a number of principal units which will be relatively autonomous as regards administration but which will be linked effectively at the research level.

The research programme of the Division has continued on the board pattern previously reported, with emphasis on, so far as diseases of cattle are concerned, contagious pleuropneumonia, infectious forms of infertility, the cattle tick, and worm parasites. In addition, following the deliberations of the Cattle Tick Research Review Committee, some work has commenced on the protozoal blood parasites which cause "tick fever" in cattle. The loss of resistance to tick fever which may result from tick control measures is a serious hindrance to their wide and thorough application in northern Australia.

Good progress has been made with the major production problems with cattle. This work aims to increase the turn-off of beef by improved husbandry in southern Australia, where European breeds find a suitable climatic environment, and to select cattle which can thrive in our hot-arid or hot-humid northern environments.

Since the knowledge gained in recent years of diseases of sheep and the advent of modern insecticides have so greatly reduced the significance of the sheep blowfly and other external parasites of sheep, research on them has been greatly reduced. Among the diseases which are receiving special attention, those of the feet (footrot and foot abscess) and of the skin (notably mycotic dermatitis), and the worm parasites of sheep continue to occupy an important place in the Division's research programme.

With wool production of such importance in the national economy, the Division continues to devote more of its resources to sheep husbandry and production than to any other field. Both in the laboratory and in the field basic physiological research is being carried out on the sheep, ranging from the factors controlling food intake and utilization, to the development of wool follicles in the foetal lamb, and to the physiological and environmental factors which determine wool production after birth and in adult life.

At the instigation of the Division, and through the medium of the Animal Production Committee and its animal industry subcommittees, the present status of animal husbandry and production investigations by Commonwealth and State organizations is now under review to reveal the nature of the major problems on which attention can most usefully be focused, so that resources can be integrated to best advantage.

During the year the Ian McMaster Wing of the McMaster Animal Health Laboratory, Sydney, was completed. In November, 1956, it was officially opened by His Excellency Sir John Northcott, Governor of New South Wales, in the presence of Lady McMaster and Miss Thelma McMaster.

Dr. M. C. Franklin, William McIlrath Fellow in Animal Husbandry, was president of the New South Wales Branch of the Australian Institute of Agricultural Science during 1956-57.

Dr. R. T. Clark of the United States Department of Agriculture continued his work at the McMaster Animal Health Laboratory, during the tenure of a Fulbright Fellowship; and a number of F.A.O. and Colombo Plan workers also spent periods working in the Division.

Grateful acknowledgement is made to the university and departmental authorities who have collaborated with the Division throughout the year, and to the Wool Industry, the Australian Meat Board, and the Australian Dairy Produce Board, for the financial assistance which they have so generously given.

2. ANIMAL HEALTH RESEARCH LABORATORY, MELBOURNE.

(Division of Animal Health and Production.)

The programme of work includes investigations of some major animal diseases of national importance. During the year final reports of representative committees on " toxaemic jaundice " of sheep (*see* Chapter VII., Section 17) and on Kimberley horse disease (*see* Chapter V., Section 11), both under the chairmanship of Dr. L. B. Bull of this Laboratory, were issued. They bring to a satisfactory conclusion investigational work performed here by the Organization's workers with the collaboration, mostly on field aspects, of State or Territories departmental officers throughout Australia.

Other investigations include studies on plant poisons (*see* Chapter V., Section 11); avian leucosis (*see* Chapter V., Section 11); toxicity of large rations of wheat (*see* Chapter VII., Section 12); infertility and physiology of reproduction in sheep (*see* Chapter VII., Section 13); copper metabolism of sheep (*see* Chapter VII., Section 17); brucellosis of sheep (*see* Chapter VII., Section 17); pleuropneumonia of cattle (*see* Chapter VIII., Section 2); brucellosis of cattle (*see* Chapter VIII., Section 2); copper metabolism of cattle (*see* Chapter VIII., Section 2); infertility in dairy cattle (*see* Chapter VIII., Section 2); and haematuria vesicalis (*see* Chapter VIII., Section 2).

During the year, the Officer-in-charge attended, as the Australian delegate, an international conference at Khartoum on pleuropneumonia of cattle.

3. McMASTER ANIMAL HEALTH LABORATORY, SYDNEY.

(Division of Animal Health and Production.)

With the completion of the Ian McMaster Wing the additional laboratory space available in the main building has relieved the previous congestion. A dam and spray irrigation plant have been installed on the Parasitology Block of the F. D. McMaster Field Station. It is proposed to establish an area of improved pasture for associated parasitological studies.

The appointment of an experienced veterinarian to act as a field officer has enabled work to be intensified on such problems as footrot and mycotic dermatitis.

Major investigations include a study of the heritability of fleece characteristics (*see* Chapter VII., Section 14); studies on internal and external parasites of sheep (*see* Chapter VII., Sections 18 and 19); drought feeding and the utilization of low-quality roughage (*see* Chapter VII., Section 11); fattening of beef cattle (*see* Chapter VIII., Section 7); and certain diseases of the feet and skin of sheep (*see* Chapter VII., Section 17).

4. VETERINARY PARASITOLOGY LABORATORY, YEERONGPILLY, QUEENSLAND.

(Division of Animal Health and Production.)

This Laboratory was established in 1948 to investigate parasites affecting live-stock, particularly those of importance to Queensland. Attention has been directed mainly to parasites of cattle. The Laboratory also provides accommodation and facilities for officers of the Division of Entomology whose investigations concern the control of the cattle tick, *Boophilus microplus*. Facilities for field work are provided by Amberley Field Station, near Ipswich.

Close liaison is maintained with the Queensland Department of Agriculture and Stock, and with the Faculty of Veterinary Science, University of Queensland.

Investigations in progress include studies on: Parasitic gastro-enteritis of cattle (*see* Chapter VIII., Section 3); and on cattle ticks and cattle-tick fevers (*see* Chapter VIII., Section 4).

5. F. D. McMASTER FIELD STATION, BADGERY'S CREEK, NEW SOUTH WALES.

(Division of Animal Health and Production.)

Seasonal conditions have again been difficult in this environment. No water has run into dams since July, 1956. Since then 11.80 inches of rain have been recorded, but there have only been three falls which were of benefit to pastures. Reserves of water for irrigation of established pastures were virtually exhausted by 30th April, 1957.

Developmental work during the year has included the laying out of a further irrigation project and the excavation of a new dam. Cattle yards have been renovated and altered, and a new feeding shed has been built to handle the increased dairy herd.

Major investigations on the Field Station are: Studies on inbred flocks of Australian Merinos (*see* Chapter VII., Section 14); inheritance of component fleece characters (*see* Chapter VII., Section 14); studies on twins (*see* Chapter VII., Section 14); development of the Zebu cross dairy herd (*see* Chapter VIII., Section 6); studies on hair growth of cattle (*see* Chapter VIII., Section 6); and studies on the sweating of cattle (*see* Chapter VIII., Section 6).

6. SHEEP BIOLOGY LABORATORY, PROSPECT, NEW SOUTH WALES.

(Division of Animal Health and Production.)

Further progress has been made in developing facilities for research. The second animal house for experimental sheep has been completed, and work has begun on the building of the main laboratory block. The climate rooms, mentioned in previous reports, have been completed and tested, and experimental work has been initiated; this work is planned to provide information on the influence of climate on the sheep, especially in regard to wool growth, reproduction, and nutrition.

During the year the transfer of the staff and equipment of the former Tracer Elements Section from Melbourne to Prospect was completed. A small laboratory has been set up for the handling of radioactive materials. Most of the equipment needed for a wide range of biological tracer work is now on hand. The assay of tritium by internal gas-counting has been developed. Work is proceeding on other methods of detecting radioisotopes and on the use of labelled compounds for measuring the rate of passage of material through the sheep's rumen. A study of protein biosynthesis in the sheep, by tracer techniques, has been commenced; for this work, methods of separating amino acids are being developed.

The Fleece Analysis Laboratory continues to provide a service for fleece and cattle hair measurements for some of the research projects within the Division, described in Chapter VII., Sections 14 and 16, and in Chapter VIII., Section 7. A total of 38,610 measurements were made on wool samples, and included determinations of clean scoured yield; clean wool weight per unit area of skin; staple length and crimp; fibre length, diameter, and density; and wax, suint, and vegetable matter contents. A further 840 measurements of weight per unit area of skin, fibre length and diameter, and medullation were made on cattle hair samples.

7. Regional Pastoral Laboratory, Armidale, New South Wales.

(Division of Animal Health and Production.)

The Regional Pastoral Laboratory at Armidale and its associated Field Station, " Chiswick ", were established in 1947. At present the research team consists of officers of the Divisions of Animal Health and Production, Plant Industry, Mathematical Statistics, and of the Wildlife Survey Section.

Investigations in progress by officers of the Division of Animal Health and Production include: Lambing behaviour in maiden and mature ewes (*see* Chapter VII., Section 13); double joining of ewes (*see* Chapter VII., Section 13); effect of husbandry practices on lamb mortality (*see* Chapter VII., Section 13); sheath rot in wethers (*see* Chapter VII., Section 17); Darling pea poisoning (*see* Chapter VII., Section 17); studies on internal parasites (*see* Chapter VII., Section 18); phalaris staggers in sheep (*see* Chapter VII., Section 21); bloat in beef cattle (*see* Chapter VIII., Section 2); supplementary feeding of beef cattle on pastures (*see* Chapter VIII., Section 7); drought feeding of cattle (*see* Chapter VIII., Section 7). " Chiswick " is one of the centres at which selection experiments, under the direction of officers of the Animal Genetics Section, are being conducted.

Based on a detailed ecological survey of the New England region, the Division of Plant Industry has an extensive pasture research programme in progress. It includes plant introduction studies, pasture ecology and autecological studies, improvement and utilization of native pastures, problems of plant nutrition, and clover nodulation. Studies on sulphur in soils, and the development, maintenance, and utilization of sown pastures are also undertaken.

Investigations in progress by the Wildlife Survey Section include survey of insect vectors of the myxoma virus, and methods of rabbit control.

At " Chiswick " an area of 1,160 acres has been cultivated and sown. In addition, approximately 980 acres of native pasture have been surface seeded with grasses and clovers. Sheep shorn in 1956 totalled 6,077, yielding 190 bales of wool or an average of 9.7 lb. per head including crutchings. A total of 1,788 lambs were weaned in March, 1957; cattle totalled 190 and horses 10.

8. National Field Station, " Gilruth Plains ", Cunnamulla, Queensland.

(Division of Animal Health and Production.)

In 1956, the annual rainfall was again well above the mean of approximately 13 inches. A total of over 31 inches was recorded, over 27 inches of which fell in the first seven months of the year.

In general, pastures were satisfactory throughout the year. Although less than 4 inches of rain fell during the last five months, young sheep grew well. Body weights off-shears of medium-wool Peppin ewes, approximately sixteen months old, averaged 85 lb.

The sheep breeding experiments AB1 and AB4 have been continued (*see* Chapter VII., Section 14). A further experiment, AB5, which deals with the interaction between small differences in heredity and large differences in environment, has been commenced (*see* Chapter VII., Section 14). Sheep in this experiment are run both at " Chiswick " Field Station, Armidale, and " Gilruth Plains ".

9. National Cattle Breeding Station, " Belmont ", Rockhampton, Queensland.

(Division of Animal Health and Production.)

" Belmont ", situated on the Fitzroy River some twenty miles north of Rockhampton, was acquired by the Australian Meat Board and made available to the Organization in 1953 for work on beef cattle production. The main programme of the station, which is 7,000 acres in area, and has a carrying capacity of 1,400 head, is directed towards studies in adaptation of British breeds and their crosses with exotic breeds to a tropical environment.

The main features of recent seasonal conditions were the heavy rains of the autumn of 1956 which continued into early winter. Although the spring was relatively dry, extremely heavy falls were received during December. Three separate moderately high floods were experienced, but damage to fences and disturbance to stock management were not serious. Rainfall for the first three months of 1957 was well below average, with high temperatures and severe water loss from both surface catchments and soils. However, generally over the period the pasturage available has been more than sufficient for the numbers of stock carried.

Improvements completed during the year include the erection of a new bachelors' quarters and associated dining-room, and cottage for a married couple; the clearing of a considerable area of rough softwood scrub, and the construction of four small catchment tanks. The access road to the property has been improved by grading, forming, and gravelling, to provide an all-weather exit.

The fourth series of experimental matings was successfully completed during the early months of 1957. After disposal of surplus animals, stock numbers have now reached 1,400.

Preliminary results and a progress report are given in Chapter VIII., Section 8.

10. Poultry Research Centre, Werribee, Victoria.

(Division of Animal Health and Production.)

Continued progress is being made with the long-range studies in population genetics. This work has been supplemented with preliminary studies designed to throw light on the mechanism of heterosis. Progress reports covering both of these aspects are detailed in this Chapter in Section 11.

For the 1956 breeding season, a total of 825 dams were used, and these were mated to 106 sires using the technique of artificial insemination. For the first time at this Centre, hatching eggs were held in storage prior to incubation for from one to fourteen days. This permitted reduction in the number of hatches and provided increased numbers of progeny per hatch. Birds on the property on April 1, 1957, totalled 5,434, of which 3,215 wer White Leghorns, 697 Australorps, and 1,522 crossbreds of various types.

11. INVESTIGATIONS OTHER THAN WITH SHEEP AND CATTLE.

(Division of Animal Health and Production.)

In addition to work at the main centres described in previous sections of this chapter, staff of the Division are also located in Western Australia, Queensland, and Tasmania, working in association with Departments of Agriculture and universities. Work is proceeding at the University of Queensland on seasonal coat changes in cattle of European origin (*see* Chapter VIII., Section 7); with the Western Australian Department of Agriculture in Perth on the copper metabolism of sheep (*see* Chapter VII., Section 17) and on the comparative biochemistry of copper and on the cobalt status of pastures (*see* this Section); and with the Divisions of Plant Industry and Soils and the Department of Agriculture in Tasmania on a project at " Frodsley " to elucidate the effects of fertilizers, including potash, on the production of pastures there and on the health and growth of sheep.

(*a*) *Studies on Microbial Metabolism* (Animal Health Laboratory, Melbourne).—The investigation of the nutritional requirements of *Asterococcus mycoides,* the causal organism of contagious pleuropneumonia of cattle, has continued. *A. mycoides* differs greatly from the majority of bacterial pathogens of animals in its requirements for growth in artificial culture. A basal medium containing 31 selected chemical components in measured quantities still required supplementation with some crude materials not chemically defined before growth of the organism occurred. The effects of added lactate, catalase, albumin, and " Tween 80 ", and of aeration, were specially studied. In addition, the nucleotide composition of the ribonucleic acid (RNA) fraction of *A. mycoides* has been studied; it did not differ from that of many other bacteria. The enzymic degradation of the RNA of the organism was also investigated.

(*b*) *Studies in Population Genetics* (Poultry Research Centre).—The following findings result from the analysis of the records of the F_8 generation of pullets:

(i) The production bred flock, selected on an index combining individual and family performance, continues to show progress.

(ii) In 1955 the three inbred lines of White Leghorns were intercrossed in all six possible combinations, and analysis of the 72 weeks' production of their pullet progeny has revealed small variations in egg production. The mean level of production (hen-housed average) of the incrosses was exactly the same as that for the outbred production flock.

(iii) Selection on combined family and individual (index) bases for hen-housed egg production was exercised on the F_2 generation derived from White Leghorn by Australorp crossbreds.

(iv) An index has been derived which permits the correct amount of emphasis to be given to individual performance, full sister average, and half sister average.

(v) Estimates have been obtained, using data collected for two years, on the heritability of second-year egg production in the domestic fowl. It would appear that the heritability of this character is lower than that for the pullet year of production. The genetic correlation between first- and second-year egg production seems to be high.

(vi) Heritability of chick viability to six weeks of age has been estimated for the Leghorn population as 7 per cent. with standard error of 0.5 per cent.

(vii) Further estimates of heritability of the production index of the pullet year have been obtained from the Leghorn flock subsequent to four years of selection. Calculated from the variance between sire progenies, heritability has been estimated as 13 per cent. ± 1 per cent. for the part period (first egg to May 31) and 7 per cent. ± 1 per cent. for 72 weeks' period. Using the full sister correlation, the corresponding estimates were 14 per cent. ± 2 per cent. and 18 per cent. ± 2 per cent. In the case of the 72 weeks' period, the higher figure obtained from the full sister correlation is almost certainly inflated owing to the presence of dominance. The genetic correlation between the production index for these two periods has been consistently estimated at between 0.7 and 0.8.

(*c*) *Avian Physiology*.—The pilot experiment in which low and normal protein diets were fed to purebred and crossbred fowls failed to reveal any clear breed-protein level interaction. In the current experiment groups of purebreds and crossbreds are being subjected to treatments (one control and four treatment groups) which will impose a greater stress on the birds than the low protein diet of the pilot experiment. The treatments include diets of low protein low energy, low protein high energy, and two diets fluctuating at regular intervals from low protein to normal protein levels. These experiments are associated with a study on the possible mechanisms of heterosis.

(*d*) *Other Observations on Poultry*.—During the period July-September, 1956, samples of eggs were stored for periods varying from one to fourteen days prior to incubation. The temperature of the egg-holding room was not controlled. Hatchabilities obtained for the storage periods one to seven and eight to fourteen days were as follows:—White Leghorn—80.8 and 70.6 per cent.; White Leghorn x Australorp—81.9 and 74.1 per cent.; Australorp x White Leghorn—87.4 and 80.0 per cent.; and Australorp—72.3 and 62.5 per cent.

(*e*) *Comparative Biochemistry of Copper* (Department of Agriculture, Perth).—Experiments on the storage of copper in ducks were continued. There was little increase in liver copper until about the third week of age, and a rapid rise thereafter up to nineteen weeks when it probably nears a maximum. The intravenous inoculation of adult drakes with copper sulphate solution supported a previous conclusion that ducks are able to regulate copper storage at high levels.

(*f*) *" Walk-about " Disease of Horses* (*" Kimberley Horse Disease "; Crotalaria Poisoning in Horses*) (Animal Health Laboratory, Melbourne).—This co-operative investigation with Western Australian and Northern Territory departmental officers has been concluded with the publication of a full report. The disease is caused by ingestion of *Crotalaria retusa,* and *Atalaya hemiglauca* can no longer be considered a causal agent, although its fruits or seeds may be poisonous to horses if eaten. The ecology of *C. retusa* and the differential diagnosis of the disease have been described.

(*g*) *Plant Poison Studies.* (i) *Plants Containing Pyrrolizidine Alkaloids.*—Arising from the investigation of crotalaria poisoning of horses and heliotrope poisoning of sheep owing to pyrrolizidine alkaloids, general studies of the pathological and pharmacological effects of alkaloids of this group, which occur in a number of Australian plants, have been undertaken in association with the Organic Chemistry Section of the Division of Industrial Chemistry. For these studies rats are being used in order to elucidate the mechanism of the action of the alkaloids and its association with their chemical structure.

(ii) *Other Plants.*—Experiments with small laboratory animals are being made to facilitate the isolation of the toxic agents in *Atalaya hemiglauca* and to determine the nature of the damage produced by alkaloids of *Lupinus varius* L.

(*h*) *Microelement Studies in Western Australia* (Department of Agriculture, Perth).—A number of liver and plant samples have been analysed for copper and cobalt content for field officers of the Department of Agriculture.

(*i*) *Avian Leucosis* (Animal Health Laboratory, Melbourne, and Poultry Research Centre, Werribee).—An experiment has been set up to determine the effect of isolation during the brooding period, on the incidence of leucosis during adult life.

12. Animal Genetics.

(Animal Genetics Section.)

The Animal Genetics Section aims to investigate the possibility of applying genetics to animal breeding and allied fields and to train students interested in the subject.

One M.Sc. student and one Ph.D. student completed their studies this year. One third-year student completed third year and is now taking honours with a view to proceeding to a Ph.D. degree. In addition, four students (two on C.S.I.R.O. staff and two on State department staffs) are studying for Ph.D. degrees in genetics and two are near the end of their M.Sc. studies. Thirty lectures are being given to second-year science students. The course of 50 lectures for post-graduate students has been expanded and taken over by the Zoology Department. A majority of the lectures is given by Animal Genetics Section staff. Dr. Hoffman has joined Dr. Grigg in Adelaide to study the structure of chromosomes and other cell inclusions by electron microscopy. An animated cartoon film showing mitosis for teaching purposes is now nearly ready for shooting.

(*a*) *Genes and Chromosomes.*—Three echidnas have been obtained and tissues prepared for examination of the amount of nucleic acid per nucleus. A paper on crossing-over in *D. melanogaster* has been published and one on the effect of age on coincidence and crossing-over has been submitted for publication. The work shows that both age and the presence of inversions increase recombination and decrease coincidence. A paper on the effect of age and temperature on mutation rate in *D. melanogaster* has been prepared for publication. The work has shown that heat shocks of 38° C. have no effect on mutation rate in larvae but increase the rate in adult males. Heat shocks of 40° C. have no effect on adult males or possibly lower the rate below normal. Mutation rate declines with age of male, and the effect of temperature on males of the same age is to reduce mutation rate. A method of double embedding specimens for ultra-thin section cutting with a diamond knife (a personal gift from Professor Fernandez-Moran to Dr. Hoffman) is now giving consistent results which provide sections for the electron microscope. These show very good contrast and allow treatment with reagents prior to observation. Interphase and prophase chromosomes have been shown to consist of a spiral filament of 50-70Å set in a meshwork of finer non-spiralized filaments. The non-spiral filaments are protein, the spiral ones have a central core of nucleic acid, and a tubular sheath of protein. The nucleo-protein spiral which has a diameter of 150-200Å spirals into a thicker structure at prophase with a diameter of about 1,000Å. Mirsky's technique of isolating " chromosomes " has been shown to result in preparation of random pieces of tissue torn from the nucleus with no particular relationship to chromosome structure. Mitochondria have been shown to arise by a process of budding from the nucleus. Work is in progress in collaboration with the University of Adelaide and Sir Macfarlane Burnet on nucleo-cytoplasmic transfer. We are grateful for the use of the electron microscopes of these two collaborators. Twelve histidineless mutants have been isolated in *Neurospara crassa*. Of these, three are the same as or allelic with previously known mutants and two are allelic with each other and closely linked with K34. Four of the mutants accumulate imidazole compounds, all compounds being different.

(*b*) *Myxomatosis.*—Selection of rabbits for resistance to KM_{13} continues. Owing to high mortality amongst challenged rabbits, much of which is due to secondary infections, the size of the selected population is still small and the third generation has not yet been passed. The time taken to kill a rabbit has been greatly increased, and two offspring from parents with one or more selected parents survive for every one offspring of controls. A system of mating which will enable heritability of resistance to be calculated is now in operation. The correlation of response to different antigens is still being studied. Myxoma virus cannot yet be isolated in sufficient quantity to be used dead; in the meanwhile response to other pox viruses as well as live myxoma plant viruses and paramecium is being measured in the same rabbit. The object is to see to what extent ability to acquire immunity to one virus may be associated with ability to acquire immunity to others; in particular, to find out how closely related the antigens must be to give correlated responses. This study is paralleled in mice using species of ciliates as the antigens.

(*c*) *Serology.*—A quantitative score of anaphylaxis has been developed which has been used to study the effect of different sensitizing and shocking doses on anaphylaxis. The technique should make it possible to assay very small quantities of antigen. A method of assaying virus on a single rabbit with a high degree of accuracy has also been developed.

(*d*) *Mice.*—Lines selected for sensitivity to oestrogen given by various routes continue to respond to selection. Nothing new has emerged from these lines this year. Work on the inbred lines continues. A final measurement of variability between sublines will be made this year, after which this investigation will be discontinued for lack of space in the mouse house. The object is to determine the rate of origin of new variation by mutation. The selection experiment in which tabby mice were used to produce variation in vibrissa number, which is otherwise virtually invariant, is now in its fifth generation. Selecting on tabby has changed vibrissa number in tabby mice and has also affected vibrissae in normal sibs in a way never observed in unselected stocks, which shows that appropriate treatment can make an otherwise invariant character respond to selection. Work on the effect of X-rays on mast cells has been completed. Phenocopies affecting vibrissae in mice have been produced by X-radiating pregnant females between the 12th and 14th day of gestation. A new investigation into the differences between inbred strains of mice using skin grafting has been begun. Study of the role of sebaceous glands in the growth of the mouse coat has continued to make progress. Correlation of sebaceous gland abnormalities with pattern of hair growth in various mutant strains of mice has been established. A detailed study of the development of the coat in " fuzzy " mice has been commenced.

(*e*) *Silliac.*—The use of the Silliac electronic computer has been explored, and programmes have been written for the commonly used statistical analyses. A set of programmes has been written which simulate genetic events presumed to go on during the evolution of a population under selection. These programmes have been run through, and changes in gene frequency resulting under different sets of conditions have been plotted together, with variances of response to selection. The main conclusion so far is that linkage of more than 2.5 per cent. recombination value has little if any effect on the response of a population to selection.

(*f*) *Sweat Glands in Cattle.*—The work of the Animal Genetics Section on the adaptation of cattle to hot climates is reported in Chapter VIII., Section 9.

(*g*) *Genetics of Sheep.*—The work of the Animal Genetics Section on the genetics of sheep is reported in Chapter VII., Section 15.

VI. NUTRITION.

1. General.

Basic knowledge is lacking of the complex chemical and biochemical process by which the ruminant animals deal with their fodder and convert pasture plants both for their own well-being and the production of useful animal products. An exact knowledge of the nutritional elements required to maintain flocks and herds in normal health is essential to the solution of problems imposed by climate and terrain on the pastoral industry in Australia. The Division of Biochemistry and General Nutrition in Adelaide studies this aspect of the animal industries, its researches being confined mainly to the nutritional biochemistry of the sheep.

Many applications arising from these studies have already found their way into practice to increase materially the overall efficiency of sheep husbandry. Some of these discoveries, for example, those which led to a realization of the nutritional importance of traces of heavy metals, cobalt, copper, zinc, &c., have been responsible for revolutionary changes in Australian agricultural practices.

The current investigations of the Division are described in this Chapter, in Chapter III., Section 8, and in Chapter VII., Sections 2-9.

The Organization's other investigations bearing on sheep nutrition are reported in Chapters III., V., and VII.

Division of Biochemistry and General Nutrition.—The research programme of the Division based on the nutrition of the ruminant animal has continued upon the broad pattern set in previous years. Fundamental studies of the nutritional factors that are essential to ensure the normal health and productivity of wool sheep have been continued and the knowledge so gained has been applied for the solution of problems encountered by the pastoral industry.

During the year a highlight in the application of these basic studies has been the advance made towards the perfection of the heavy pellets which will remain in the rumen and provide a continuous supply of cobalt and other therapeutic substances to grazing sheep. There is the hope that the application of these novel methods to the husbandry of flocks on deficient terrain and on pastures in which early growth of *Phalaris tuberosa* predominates may obviate the necessity for frequent mustering and drenching.

During the year the Australian National University conferred upon the Chief of the Division the honorary degree of Doctor of Science in recognition of his contributions to science in Australia.

A mass spectograph was installed in the Division during the current year, and will provide a means of tracing the utilization of nitrogen ^{15}N in the study of protein turnover.

The Division continues its various studies at its three field stations. Experiments on salt tolerance, chronic fluorosis, and supplementary feeding are being conducted at Glenthorne; the effects of copper and cobalt deficiencies in sheep grazing are being studied at Robe; and at Brecon and several localities in the south-east of South Australia a series of experimental trials are being conducted to test the capacity of cobalt pellets to protect flocks and herds from phalaris staggers.

In this latter project the Division is collaborating with the Division of Plant Industry and the Division of Animal Health and Production in testing the pellets on established phalaris pastures at Armidale, New South Wales, Canberra, Australian Capital Territory, and Kojonup, Western Australia.

Grateful acknowledgment is made to all those establishments which have helped the Division in various ways during the year.

2. Nutrition and Wool Production.

(Division of Biochemistry and General Nutrition.)

Earlier research has provided understanding of the relationship between nutrition and wool production and has demonstrated the interplay of fodder proteins, which are the raw material from which wool fleece is synthesized, with those other constituents in the fodder which in effect fuel the factory. Broadly, these experimental investigations have provided the foundation upon which policies of pasture improvement, of drought feeding, and of many other sheep husbandry practices must rest if they are to be securely based. Experimental work on many aspects of this broad problem is being pursued vigorously.

3. Studies of the Metabolic Processes of Sheep.

(Division of Biochemistry and General Nutrition.)

During the year, the results of a series of investigations that have been made to extend knowledge of the way in which the sheep deals with matter and energy have stressed further that channels of intermediary metabolism relatively unimportant for other animals are of prime importance to sheep. These particular metabolic pathways are concerned mainly with the metabolism of acetic, propionic, and butyric acids, and it has become clear that they are dependent upon the cobalt-containing accessory food factor, vitamin B_{12}, and probably upon pteroylglutamic acid.

Studies of the carbohydrate metabolism of sheep and of new-born lambs have been extended to provide further information on the utilization of sugar by ruminants.

An understanding of these aspects of ruminant physiology is essential for the recognition and correction of metabolic disorders. The individual researches are referred to in more detail in Chapter VII.

4. Energy Metabolism of the Sheep.

(Division of Biochemistry and General Nutrition.)

Studies of the overall energy transactions of the sheep have been continued. During the year, while the mass spectograph for the determination of $^{14}N/^{15}N$ ratios was being assembled, the metabolism chambers have been used for the study of disordered metabolism due to vitamin B_{12} deficiency, and for other studies. The broader basic study of the interaction of protein metabolism with the overall energy metabolism of the sheep is being extended with the use of new techniques made possible by the mass spectrograph.

Some aspects of the application of the knowledge of energy metabolism to other problems of sheep nutrition are referred to in Chapter VII.

5. Microbiological Processes of Rumination.

(Division of Biochemistry and General Nutrition.)

Earlier work has shown the primary dependence of the sheep upon fermentative reactions and certain syntheses brought about by microorganisms within its paunch, and various aspects of the requirements and activities of these microorganisms. One of the more important chemical changes that occur within the rumen contents is the conversion of part of the protein in the fodder to bacterial protein and hence, in part, to protozoal protein. These latter proteins provide an important part of the substrate for wool production, and as they differ in their capacity to meet the special requirements of this physiological process, knowledge of their amino acid composition is essential for the understanding of the nutritional requirements of the wool sheep and of its efficiency as a convertor.

An investigation of the amino acid composition of these microbial proteins has been completed.

This and other aspects of current researches are referred to in various sections of Chapter VII.

6. SALT TOLERANCE OF SHEEP AND POTABILITY OF STOCK WATERS.

(Division of Biochemistry and General Nutrition.)

The series of experiments designed to provide basic knowledge of the tolerance of sheep to bore waters of various degrees of salinity and of various compositions will be continued over a number of years. The findings from the second of this series are discussed in Chapter VII.

7. CARBOHYDRATES AND STEREOCHEMISTRY.

(Division of Biochemistry and General Nutrition.)

During the past year work on the separation of carbohydrates by paper ionophoresis has been continued and extended to a number of rare carbohydrates to provide data necessary for their identification and for the identification of the structural features responsible for complexing with the electrolyte ions employed in the ionophoretic process. In a critical study of all methods of identification of carbohydrates, basic lead acetate and sodium arsenite have exhibited special advantages over borate that hitherto has been employed as a supporting electrolyte. The superiority of these compounds for the separation of acyclic acid sugar alcohols having the threo configuration is especially striking.

Study of the *cyclo*hexyl-idene derivatives of carbohydrates has been continued. Several new derivatives of D-mannitol, new acetals from D-fructose, and a new acetal of D-mannose have been prepared, and the cyclic acetals of aldonic acids are being studied as a basis for stereochemical studies that, inter alia, may improve knowledge of synthesis of rare sugars.

8. MINOR ELEMENT DEFICIENCIES IN ANIMALS.

(Division of Biochemistry and General Nutrition.)

Earlier studies have revealed the prime importance of traces of heavy metals in the nutrition of plants and animals.

Many of the current experiments are being conducted with sheep confined in pens or depastured at field stations situated where appreciable deficiencies prevail. These are referred to in the appropriate sections of Chapter VII. Others being conducted with plants in water cultures under glass-house conditions are referred to in Chapter III., Section 8.

Studies of copper deficiency in the rat which are being carried out to amplify and explain findings arising from experiments with copper-deficient sheep have been continued. These have further clarified knowledge of the nutritional factors and of the physiological mechanisms involved in the metabolism of copper in ruminants, and thus are leading rapidly to a better appreciation of the factors, that, in certain terrains, complicate the availability of copper within the tissues and thus give rise to what is, in effect, induced copper deficiency, under conditions where the concentration of copper in the fodder would normally be abundant for all physiological requirements. Experimental studies of sheep in which copper deficiency was induced by these factors under the controlled conditions achievable when the animals are confined to metabolism cages and to pens have been continued throughout the year. This work has led to further additions to the knowledge essential for the understanding of a variety of disabilities in grazing stock that arise from copper deficiency. Some of these investigations are discussed briefly in Chapter VII.

Further studies of the metabolism of zinc and of the protein metabolism of zinc-deficient rats were made during the period under review.

9. VITAMIN B_{12} AND COBALT METABOLISM.

(Division of Biochemistry and General Nutrition.)

A series of studies has been completed of the cobalt deficiency syndrome that has entailed experimental investigations into the production of vitamin B_{12} within the rumen and the effect that cobalt concentration has upon this synthesis, the sheep's requirements of vitamin B_{12}, the influence of cobalt concentration on the fermentative activity of rumen microflora, the nature of the metabolic lesion induced by cobalt deficiency, and several other aspects of the main problems associated with this nutritional disorder.

The researches are now converging on more detailed studies of the impaired intermediary metabolism of fatty acids in sheep that have been rendered vitamin B_{12} deficient, and in these studies the metabolic relationships between vitamin B_{12} and pteroylglutamic acid are receiving special attention. The nature and concentration of various organic acids—other than the volatile fatty acids—that occur in the blood of normal and vitamin B_{12}-deficient sheep are being investigated. Those acids that become more concentrated in the blood stream of the deficient animals have been identified by partition chromatography in silica columns. Many microbiological assays of tissues, blood, rumen and intestinal contents, etc. for vitamin B_{12} and its analogues and for frolic acid have been conducted during the year in association with research into various aspects of this deficiency disease.

Work that has illuminated further several other aspects of vitamin B_{12} deficiency in grazing ruminants is reported briefly in Chapter VII., Section 6.

10. PLANT NUTRITION.

(Division of Biochemistry and General Nutrition.)

The programme of studies of the function of zinc in plants and of the lesions that appear in pasture plants that have been rendered zinc deficient has been continued. A short precis of the findings is reported in Chapter III., Section 8.

11. PHALARIS STAGGERS.

(Division of Biochemistry and General Nutrition.)

This work is described in Chapter VII., Section 7.

12. UREA AND NITROGENOUS COMPOUNDS AS A SOURCE OF NITROGEN FOR RUMEN MICROORGANISMS.

(Division of Biochemistry and General Nutrition.)

This work is described in Chapter VII., Section 8.

VII. SHEEP.

1. GENERAL.

With a sheep population of over 150,000,000, Australia produces about one-quarter of the world's wool and about twice as much as any other country. More than one-half of the world's production of fine wool comes from our dry inland areas.

The sheep holds a unique position in the Australian economy. Wool is our major export, and primary products from the sheep industry such as wool, lamb, mutton, and hides comprise up to 45 per cent. of all Australian rural production. The sheep, too, allows of the use of vast areas of marginal land which it has not so far been practicable to use for other purposes.

Thus Australia has a vital interest in ensuring that wool can withstand the competition from artificial fibres. The remarkable success of the latter has been due in the main to the clear understanding, arising from research, of the physical and chemical properties of the new fibres. Moreover, the chemical industry established to produce them is planned as a coordinated and organized unit, which ensures maximum efficiency and minimum wastage at all stages.

It is the major aim of the Organization's integrated programme of research in aid of the wool industry to investigate every phase of sheep and wool production: soil, pastures and nutrition, genetics, animal husbandry, wool processing, textile manufacture, and the exploitation of by-products. The Organization has been given responsibility by the Commonwealth Government for carrying out this extensive programme, and special funds have been set aside for this purpose.

Soil fertility is obviously of prime importance, and outstanding results have been achieved in improving soil infertility arising from minor element deficiencies. On the plant side, too, special emphasis has been placed on pasture improvement and weed control. The work of the Organization on soils, pastures, and related matters affecting the pastoral industry is carried out by the Division of Soils and the Division of Plant Industry (see Chapters II. and III.).

Work on the sheep itself has been undertaken within the Division of Animal Health and Production (see Sections 10-19 and 21 of this Chapter) and the Division of Biochemistry and General Nutrition (see Sections 2-9 of this Chapter). The Division of Mathematical Statistics is closely associated with the breeding investigations. The Animal Genetics Section's work on sheep breeding is described in Section 15 of this Chapter, and that of the Division of Entomology on the sheep blowfly in Section 20 of this Chapter.

The Organization's work in the investigation of wool processing and wool textile problems is undertaken at the Wool Textile Research Laboratories and the Division of Industrial Chemistry (see Chapter XVI.).

2. Nutrition and Wool Production.

(Division of Biochemistry and General Nutrition.)

The special study of the biochemical mechanisms involved in the production of wool fibre that was initiated by the discovery of the influence of copper on the process of keratinization has been continued. Samples of wool grown by experimental sheep in which several degrees of copper deficiency were induced under controlled nutritional and environmental conditions have been collected and are in the course of being examined chemically and physically; a series of histological and histochemical studies have been made of the follicles at each stage of the imposed degrees of copper shortage. The results illuminate the basic processes underlying the biological synthesis of the protein, keratin, which comprises the wool fibre.

The extensive study of the interrelationships between energy metabolism, protein turnover, and rate of wool production is proceeding, and the mass spectrograph recently installed will provide a means of utilizing as a marker the nitrogen isotope, ^{15}N, in the study of protein turnover.

3. Microbiological Processes of Rumination.

(Division of Biochemistry and General Nutrition.)

The studies of the amino acid constitution of the proteins in fractions of the rumen contents that respectively were predominantly of bacterial origin and predominantly of protozoal origin have been completed. Further study of diaminopimelic acid, a characteristic constitutent of the bacterial fraction, is being made with the view to using this amino acid as a marker in physiological studies of the flow of ingested foodstuffs through the fore-stomachs, and in nutritional studies of the changes in composition that are brought about during this procession.

This work is an integral part of the study of the extent of conversion of plant protein to microbial protein brought about by the microflora and fauna within the contents of the paunch. These changes are considerable, especially with certain types of fodder, and a better appreciation of the nature and extent of them is essential for the understanding of the overall nutrition of sheep.

4. Energy Metabolism of Sheep.

(Division of Biochemistry and General Nutrition.)

During the year the calorimeters have been employed mainly for the study of the overall thermodynamic transactions in the utilization of foodstuffs by vitamin B_{12}-deficient sheep.

A microcalorimeter has been constructed for the study of the energetics of fermentation and of other chemical reactions brought about by microorganisms within the rumen contents. These studies of the energy metabolism of the ruminant have shown that the heat dissipated by the fed sheep arises from two sources; viz. the energy freed as heat from the chemical reactions that support the living processes within the tissues of the animal, and the energy freed as heat from the fermentative reactions, and from the chemical reactions that occur within the cells of the symbiotic microflora and microfauna that function within the paunch.

These experiments are being conducted to determine the extent of the energy losses brought about by these reactions.

5. Carbohydrate Metabolism of the Sheep.

(Division of Biochemistry and General Nutrition.)

Experimental studies of the carbohydrate metabolism of sheep and lambs and the relationship of this to the metabolism of fatty acids have been extended. Study of the metabolic disorder associated with altered utilization of carbohydrates in experimental sheep that have been rendered diabetic have indicated that the condition involves also changes in fat production. This aspect is being studied further to define the extent of the effect of insulin on lipogenesis in mature sheep and in lambs, and so illuminate further the differences in intermediary metabolism.

The effect of the complete lack of pancreatic enzymes that supervenes on total pancreatectomy or on ligation of the pancreatic duct has been studied, and it is clear that sheep treated in this way may be maintained in excellent condition.

An intensive histological study is being made of the pancreas of sheep and lambs. This aims at evolving staining reactions specific for the cells that produce insulin.

6. Minor Elements in the Nutrition of Sheep.

(Division of Biochemistry and General Nutrition.)

Earlier work has revealed the fact that heavy metals such as cobalt, copper and zinc play essential roles in the living processes of plants and animals. Recognition that shortages of these elements within the soils limit the productivity of certain types of terrain, sometimes very seriously indeed, and that these deficiencies may economically be made good, has revolutionized agricultural and husbandry practice in many important areas in Australia and elsewhere. With the growth of experience and knowledge of the effects that supervene on minor element deficiencies, it has become clear that the extent of areas affected in this way is very much greater than was considered probable, when, in the early stages of the investigations experiments were confined to terrain known to be seriously deficient. Correction of the disabilities imposed by deficiencies of this nature has paid enormous dividends to Australian pastoral industry, and there is prospect of even greater returns when existing knowledge is applied.

(*a*) *Cobalt Deficiency in Ruminants.*—An important series of experiments devoted to a study of the vitamin B_{12} deficiency syndrome in the sheep has been completed. This has led to an understanding of the effects of cobalt on the fermentative and synthetic activities of the rumen flora, the production of vitamin B_{12} in the rumen, the absorption of vitamin B_{12} by the sheep, the sheep's requirements of vitamin B_{12}, the storage and turnover of the vitamin, and the metabolic lesion of vitamin B_{12} deficiency.

Advances in the knowledge of the manifest changes in the rumen flora brought about by the cobalt concentration of the rumen contents have made possible very marked improvements in husbandry methods for controlling cobalt deficiency and for protecting grazing sheep and cattle from the fatal malady, phalaris staggers, which, in certain seasons, affects flocks and herds grazed on grasslands dominated by the perennial grass, *Phalaris tuberosa,* that has been exploited so extensively for sown pastures in southern Australia. The evolution and the testing of the heavy cobalt-containing pellets employed for this purpose is discussed in Section 7 of this Chapter.

Determinations of the vitamin B_{12} concentrations in bloods and livers of experimental sheep in various stages of cobalt deficiency have provided a sound basis for the diagnosis of the cobalt status of flocks and herds grazing under natural conditions.

(*b*) *Copper Deficiency in Sheep.*—The experiment is being continued with sheep confined to the copper-deficient pastures at Robe, South Australia. During the past year the observations proved that supplements equivalent to 10 mg. Cu/day elevated the concentration of copper in the livers of grossly copper-deficient sheep to normal levels within a few months, and the extent of this rise was not influenced appreciably by molybdenum (100 mg./day) nor by this level of molybdenum administered together with sulphate (2.9 g./day). Sulphate alone, however, tended to reduce the rate of accumulation of copper from the supplement. At the beginning of these treatments the livers were seriously haemosiderosed. The above treatments reduced the initial high concentrations of iron to normal levels. The copper concentration remained extremely low in the livers of the copper-deficient groups that received no supplements of copper, and the high concentration of iron either remained stationary during this period or increased. The molybdenum supplement induced in the livers an appreciable rise in the concentration of copper and a decided fall in the concentration of iron; sulphate had no influence.

The series of semi-intensive studies are nearing completion of sheep confined to pens on copper-deficient rations and have led to a sounder appreciation of the copper-deficiency syndrome and of the similar syndromes induced by agencies other than copper shortage in the fodders. The findings are being set out in a series of papers in which the effects of copper deficiency and induced copper deficiency on the health and productivity of sheep and lambs and on the production of wool fleece will be reported and the underlying mechanisms discussed. The long series of studies of copper deficiency in rats kept under laboratory conditions have provided basic information necessary for the interpretation of the findings from experiments with sheep in pens and sheep under natural conditions.

7. PHALARIS STAGGERS AND THE PROVISION OF COBALT.

(Division of Biochemistry and General Nutrition.)

The high-yielding perennial pasture grass *Phalaris tuberosa* in association with subterranean clover has been widely used with great advantage for pasture improvement in southern parts of Australia, and especially for the establishment of productive pastures on the extensive tracts of deficient trerrain recently brought into prolific bearing by correction of the limitations imposed by deficiencies of zinc and copper.

Sheep and cattle confined to pastures dominated by *P. tuberosa* are subject to the hazard of a nervous malady, phalaris staggers, which is frequently fatal and which, in some seasons and in certain areas, can lead to the loss of practically all stock grazed exclusively on the new growth of this plant. Earlier work has shown that a supplement of cobalt will completely protect sheep (and almost certainly cattle) from this malady.

Experimental observations in the laboratory have indicated that cobalt exerts its activity by stimulating within the rumen the proliferation of microorganisms capable of destroying the toxic principle of phalaris before it is absorbed into the animal. Very little cobalt is necessary, but to be effective the means of administering the supplement should ensure that the cobalt in solution within the rumen contents is kept continually above a certain limiting concentration. Advantage has been taken of the fact that small heavy objects swallowed by ruminants do not pass through the alimentary canal but remain either in the rumen or in the contiguous fore-stomach, the reticulum, the contents of which mix freely with those of the rumen. If, then, objects can be contrived of a size, shape, and density appropriate to ensure that they remain in the fore-stomachs and give up to the rumen contents sufficient cobalt (between 0.1 and 1.0 mg. Co/day) to meet all requirements of the microorganisms, the expensive and irksome task of frequent mustering and drenching will be obviated.

A number of different types of such objects have been contrived and are being subjected to critical experimental tests with sheep in pens and with flocks depastured under various natural grazing conditions. One of these types of pellets comprised of approximately 5 g. of a mixture of 75 per cent. cobaltic oxide and 25 per cent. china clay has been subjected to an extensive series of tests, and because of the findings from these it is proposed to recommend the provisional commercial manufacture and vending of similar but denser pellets comprised of 90 per cent. cobalt and 10 per cent. china clay.

It is aimed to develop pellets that will meet the cobalt requirements of the sheep for some months, and there is every hope that this period of effectiveness can be extended for some years, if not for the natural life of the animal.

No further studies of phalaris staggers were undertaken at the Division's field station at Keith during the period under review, as dilution of the previously phalaris-dominant pastures there by other fodder plants precluded an outbreak of this malady. A newly cleared area close by has been sown with *Phalaris tuberosa* to provide suitable pastures for further studies.

A series of trials were undertaken during the year to determine whether cobalt pellets would effectively protect flocks confined to pastures dominated by *Phalaris tuberosa.* Collaboration was sought, and was readily given by eighteen South Australian graziers upon whose properties there was a history of well-authenticated outbreaks of phalaris staggers. These properties, distributed between the Adelaide Hills and the lower south-east of South Australia, are on terrain comprised of a wide variety of soil types ranging from deep sands to heavy black clay. The *Phalaris tuberosa* established on them was possibly of more than one strain and the period since establishment ranged over 60 years—most of them, however, were sown from five to fifteen years ago. During March, 1957, cobalt pellets were administered to more than 1,800 sheep (Merinos and crossbreds), and control groups comprised of more than 600 comparable animals were run with them on these pastures.

In South Australia the early part of autumn 1957 remained unusually dry and so was not generally conducive to the rapid growth of phalaris. Nevertheless in more favoured localities two serious outbreaks of phalaris staggers began during May, eight weeks after the pellets were administered, and another during June, after twelve weeks. The untreated animals were removed from the phalaris pastures at these sites soon after the symptoms appeared in some of them; there is little doubt that all would have succumbed to the malady had they been left there. At Glenroy, eight weeks after the pellets had been administered, there were no cases among 70 sheep that had received them and ten among the 30 that had not. At Bool Lagoon there were three cases among 223 that had received pellets and 30 among the 50 that had not. At Maaoope, twelve weeks after the pellets were administered, there were two cases among the 126 sheep that had received pellets and thirteen out of 37 sheep that had not.

The few sheep that developed the symptoms after having been treated with pellets were slaughtered. Careful search of the intestinal tract proved that the pellets had been rejected. At one of these sites exposure of the treated flock a second time to the hazard indicated by the appearance of further cases that there was a tendency for the sheep to lose these particular pellets. At worst, however, 93 per cent. of the treated sheep were protected from phalaris staggers under conditions that accounted for between 30 and 60 per cent. of the untreated members of the flock, and which would, with little doubt, have led to the loss of all of them had they not been withdrawn to other pastures.

A pellet recovered from one sheep that had developed phalaris staggers was heavily coated with a deposit of calcium hydrogen phosphate thick enough to prevent the passage of cobalt from the pellet to the rumen contents.

Similar tests are being conducted in collaboration with the Divisions of Plant Industry and of Animal Health and Production on established phalaris pastures at Armidale, New South Wales, at Canberra, Australian Capital Territory, and at Kojonup, Western Australia.

Characteristics necessary to ensure the retention of heavy pellets are being studied further, and other forms of cobalt-containing pellets are being tested.

The work of the Division of Animal Health and Production on phalaris staggers is reported in Section 21 (*b*) of this Chapter.

8. Urea Nitrogen as a Source of Nitrogen for the Nutritional Production of Protein.

(Division of Biochemistry and General Nutrition.)

An experiment to determine how the useful protein content of silage might be increased economically by adding urea or other simple nitrogenous sources during the ensiling process is in progress. Silages made by different treatments and with different additions are being subjected to feeding tests with sheep penned at Glenthorne.

9. Salt Tolerance and Potability of Stock Waters.

(Division of Biochemistry and General Nutrition.)

The second of the series of experiments that are being carried out to determine the capacity of sheep to tolerate high concentrations of inorganic salts in their drinking water was completed during the year and a third experiment was begun.

In the one that was completed the effects were determined by adding magnesium chloride to drinking water containing magnesium and sodium chlorides equivalent to a total salt concentration of 1.3 per cent., the magnesium chloride being added in concentrations of 0, 0.02, 0.05, 0.10, 0.20, and 0.50 per cent. The concentrations of salts were increased gradually to the desired levels over a preliminary period of three months. Experimental observations were carried out over sixteen months. No untoward effects were observed in the sheep confined to the saline waters containing up to 0.10 per cent. of magnesium chloride. Concentrations above this proved toxic, and the experimental animals offered saline waters containing 0.2 and 0.5 per cent. magnesium chloride refused their fodder, became emaciated, and were removed from the experiment after three months. No consistent differences in the concentrations of sodium, potassium, calcium, magnesium, and chlorine were noted in the blood plasma of the experimental animals as a result of the treatments.

In the third experiment now in progress the effects of replacing sulphate for part of the chloride in a saline water containing 1.3 per cent. sodium chloride are being studied.

10. Metabolism in Pregnant Ewes.

(Division of Animal Health and Production.)

Pregnancy Toxaemia Investigations (Sheep Biology Laboratory).—Work to elucidate the aetiology and pathogenesis of pregnancy toxaemia has continued. This disease is of major economic importance in Australia. Further studies have been made on naturally occurring cases and on normal and fasted pregnant ewes. Several tentative conclusions now appear justified.

The drain by the foetus on limited supplies of glucose can completely account for the hypoglycaemic response of ewes in late pregnancy to under-nutrition or fasting. The resulting hyperketonaemia is primarily the result of a failure in acetyl Coenzyme A utilization in liver and acetoacetate utilization in peripheral tissues, rather than of excessive rates of fatty acid oxidation in liver tissue. Glycerol invariably lowers high blood-ketone levels; glucose rarely does so. This indicates a metabolic block in glucose dissimilation at a level above glyceraldehyde-3-phosphate, comparable to that in severe diabetes in man and other species. Other observations support the hypothesis of a severely diabetic metabolism; the available data suggest that this is primarily an effect of a hormone imbalance in the direction of excessive adrenal-cortical activity.

These metabolic abnormalities affect particularly the liver, in which they are merely an exaggeration, in response to the stimulus of hypoglycaemia, of effects seen to a considerably lesser degree in fasted non-pregnant ewes. Peripheral tissues are undoubtedly affected, but the extent to which the interference with glucose metabolism affects brain tissue and hence accounts for clinical abnormalities is as yet uncertain. There is evidence, however, that the most severe clinical signs in hypoglycaemic ewes are associated with severe hyperketonaemia; the severity of the latter appears to be correlated with the severity of the metabolic block.

The general hypothesis, that pregnancy toxaemia, regardless of predisposing conditions, is primarily due to glucose insufficiency *per se* and that failure to respond to glucose or glycerol therapy is due to permanent brain damage, has been shown to be untenable. In field studies on undernourished pregnant ewes, clinical signs of pregnancy toxaemia occurred in many ewes in which blood-glucose levels were normal; the diabetic nature of the syndrome was confirmed by the presence of hyperketonaemia. Pronounced adrenal hyperactivity preceding the onset of clinical signs was indicated by the presence of a complete wool " break ". None of fifteen affected ewes responded to glycerol therapy, regardless of how early or how frequently it was administered.

Data have been compiled for the activities of various enzyme systems and enzyme-catalysed reactions in liver, brain, and kidneys of normal, fed sheep. These data form the basis of current investigations into enzyme systems in fasted pregnant ewes and in ewes with pregnancy toxaemia.

11. Drought Feeding and Allied Problems.

(Division of Animal Health and Production.)

Drought feeding experiments with sheep have been continued by the McMaster Laboratory, in collaboration with the New South Wales Department of Agriculture at the Veterinary Research Station, Glenfield. Financial support was again provided by the New South Wales Graziers' Association from the Burdekin Bequest Fund.

(*a*) *Utilization of Low-quality Roughage by Merino Sheep.*—Groups of two-tooth ewes and wethers are being fed a low-quality cereal straw chaff ration *ad lib.* plus various supplements, which are given twice weekly. The experiment has been in progress for twelve weeks. The body weight changes, survival rate, and general performance have been satisfactory when equal nitrogen intakes are provided by supplements such as linseed meal, coconut meal, cottonseed meal, lucerne chaff, and linseed meal, or lucerne chaff plus wheat and a urea-sulphate mixture. When peanut meal and meat meal were fed as supplements providing the same mean daily nitrogen intake as the above, the performance of the sheep was less satisfactory.

When wheat or oat grain replaced the protein-rich supplements, the performance was also less satisfactory, but addition of a urea-sulphate mixture to the grain supplement has improved performance, mean body weight, and survival rate.

(*b*) *Metabolism Balance Studies*.—Metabolism experiments have been carried out in cages at the McMaster Laboratory to determine nitrogen balances and the digestibility of protein, crude fibre, organic matter, and dry matter of cereal straw containing 3.8 per cent. crude protein, when fed alone or with supplements of linseed meal, lucerne chaff, meat meal, or safflower meal. The quantity of each supplement has been adjusted to provide 5.2 g. nitrogen per sheep per day.

Negative nitrogen balances, on the straw alone, have ranged from 1.07 to 1.6 g. N per head per day. Nitrogen balances in the supplemented groups have been positive and have ranged from 0.3 to 1.8 g. per day. Apparent digestibility of the crude protein of the cereal straw alone was only 12.7 per cent.; that of the straw plus supplements ranged from 52.2 to 59.1 per cent.

The digestion coefficients of the organic matter in the straw only and straw plus safflower meal rations were 51.2 and 50.9 per cent. respectively, whereas those for the straw plus linseed meal, lucerne chaff, or meat meal rations were 54.0, 55.2, and 55.1 per cent. respectively. These results were in accord with the performance of the larger groups of sheep fed similar rations in the drought feeding experiments at Glenfield during the previous year, when the group supplemented with safflower meal performed poorly.

12. TOXICITY OF LARGE RATIONS OF WHEAT.

(Division of Animal Health and Production.)

This investigation has been continued at the Animal Health Research Laboratory, Melbourne. No evidence was obtained that histamine, either enterogenous or endogenous, plays a significant part in the condition; the concentration in the rumen never exceeded $3.3\mu g./ml.$, blood histamine did not increase, and the antihistamine compound " Phenergan " had no effect upon the outcome. Further evidence was obtained that the progressive severe fall in plasma volume is important; following administration of otherwise fatal doses of wheat, intravenous infusion of physiological sodium chloride solution, maintained at rates (3-5 ml./min.) sufficient to prevent the characteristic increase in plasma specific gravity and the early anuria, prevented death, and illness was either absent or comparatively mild. Blood pH fell temporarily to as low as 7.20, and lactate rose to as high as 11 m.-mole/1., which suggested that this was due to absorption of lactic acid from the highly acid rumen or lower portions of the bowel; and the ruminal contents became unusually bulky and fluid, which suggested even greater sequestration of extracellular water in the hypertonic ruminal fluid than otherwise occurs; but after 24-48 hr., ruminal lactic acid began to be replaced by volatile fatty acids, blood values returned to normal, and the animals recovered. In further attempts to assess the importance of the ruminal toxin first described by Dougherty of the United States of America, sheep were given a long series of injections of formalin-treated material until their serum gave evidence, by the precipitin reaction, of containing antibody against some constituent, although not necessarily the toxin itself; but they succumbed as readily as unprepared sheep when fed excessive amounts of wheat. Its role is therefore still not clear.

13. INFERTILITY AND PHYSIOLOGY OF REPRODUCTION.

(Division of Animal Health and Production.)

(*a*) *Heat-induced Foetal Dwarfism in Sheep* (University of Queensland).—The course of pregnancy was followed in each of three differently treated groups of Peppin Strain Merino ewes. Lambs' birth weights were recorded, scale photographs taken, and dissections performed. A control group of seven ewes, maintained on a high plane of nutrition, all lambed; mean birth weight was 8 lb. 6 oz. Each of six ewes, kept on a low-plane diet, also lambed, but mean birth weight was less than the controls by 1 lb. 9 oz. ($P < 0.01$). The third group of seven, kept on the same low-plane diet, but subjected to high temperature in addition, produced only four lambs; their mean birth weight was 4 lb. 6 oz. less than the controls. Scale photographs of the lambs, and X-rays and measurements of their long bones, showed that the lambs whose mothers had been heated were miniatures. As their skeletons were much reduced in size, whereas low nutrition acting alone caused little skeletal reduction, the dwarfing was not solely due to nutritional causes.

(*b*) *Seasonal Variation in the Level of Fertility in Merino Sheep* (Animal Health Laboratory, Melbourne).—At the Tooradin Field Station in Gippsland, ewes from a flock in the Western District of Victoria, in which mating is normally undertaken in November, experienced a well-defined period of reduced sexual activity earlier in the spring. Almost all were in a completely anoestrous state in September. The level of sexual activity had increased substantially by November, but it was still significantly lower than that among similar ewes on the original property. The cause of the difference in behaviour in the two localities is being sought. Under the conditions of these observations, there was little evidence that the introduction of rams during the spring stimulated sexual activity in the Western District ewes or in ewes of two other strains.

(*c*) *Induction of Heat in Spayed Merino Ewes* (Animal Health Laboratory, Melbourne).—Observations on a small number of spayed sheep suggest that the sensitivity of Merino ewes to oestradiol benzoate is of the same order as that found in Suffolk ewes by other workers.

(*d*) *Double Joining of Ewes* (Regional Pastoral Laboratory, Armidale).—Forty-four fine-wool Merino ewes suckling lambs approximately two months old were joined with rams between 30th April and 6th June. Forty-three ewes mated and 37 subsequently lambed. All lambs were singles. Thirty-four lambs were reared, a lamb marking of 77 per cent. of ewes mated.

(*e*) *Physiology of the Foetal and Neonatal Lamb* (Sheep Biology Laboratory).—These studies are related to the investigations of neonatal mortality in lambs:

(i) *Metabolism of the Fasting Newborn Lamb*.—As determined by indirect calorimetry, the heat output of fasting newborn lambs varied from 60 to 20 kcal. per hr. according to the state of the coat—wet or dry—and the ambient temperature—12 or 21° C. Rate of heat output fell as fasting progressed, and values as low as 6 kcal. per hr. were observed. It is estimated that the total output of which a fasted lamb weighing 4 kg. is capable is of the order of 900 kcal. Substantial amounts of glycogen were present in muscle of lambs at birth, but fat was certainly the most important source of energy during the first hours of life. Utilization of protein remained low until fasting had been in progress for 24-36 hr.

(ii) *Temperature Regulation of Newborn Lambs.*—Most lambs of a group which was born under cold, wet, and windy conditions were unable to maintain body temperature immediately after birth, but could do so within about 3 hr. In some lambs, the rectal temperature fell below 30° C. within 20 min. of birth. There was a highly significant correlation between birth weight and rectal temperature 20 min. after birth.

(*f*) *Lactation in Ewes* (Sheep Biology Laboratory, Prospect, New South Wales, and Animal Health Laboratory, Melbourne).—Between 2 and 4 hr. after parturition, the rate of production of milk in Corriedale ewes which had borne single lambs (mean 57 ml. per hr.; range 31-91 ml.) was closely similar to that in ewes of the same line which had borne twin lambs (mean 53 ml. per hr., range 21-93 ml.).

(*g*) *Influence of Light on Breeding Season of Merino Ewes.*—Ewes born during May-June, 1955, and subjected to continuous light from August, 1955, experienced oestrus during the autumn and winter months of 1956, but less regularly than similar ewes which were maintained in the normal light environment. Following an anoestrous period in all ewes in the spring, the ewes subjected to continuous light have since experienced oestrus as regularly as the ewes maintained in the normal light environment. It is evident that normal seasonal variation in sexual activity is established and maintained under conditions of continuous light.

(*h*) *Effect of Husbandry Practices on Lamb Mortality—Lambing "Off Shears" and "In Wool"* (Regional Pastoral Laboratory, Armidale).—Over a period of five years, the loss of fine-wool Merino lambs between birth and marking was 13 per cent. of lambs born in the "off shears" treatment and 17 per cent. in the "in wool" treatment. Lamb marking percentages were 79 and 75 respectively. In four of the five years, losses were lower in the "off shears" treatment and the overall difference of 4 per cent. was significant at the 5 per cent. level. In each of the five years, lambing commenced in mid October, but observations will in future be made on lambings beginning in early September.

(*i*) *Lambing Behaviour in Maiden and Mature Ewes.*—It is generally recognized that perinatal lamb mortality is greater in lambs from maiden ewes than in lambs from mature ewes. In fine-wool Merinos lambed under close observation, the loss of lambs born was 18 per cent. in mature ewes and 36 per cent. in maiden ewes. The higher loss of lambs in maiden ewes was mainly due to failure to establish a satisfactory ewe-lamb relationship during the first few hours after birth. The fault appeared to lie with the ewe rather than with the lamb; the main factors implicated were poor maternal instinct and abnormalities of udder secretion.

(*j*) *Factors Associated with Neonatal Mortality of Lambs* (Sheep Biology Laboratory, Prospect, New South Wales, and Animal Health Laboratory, Melbourne).—Intensive observations at lambing in a small group of ewes from a Corriedale flock in which high neonatal mortality had been experienced for a number of years indicate that the adverse weather normally experienced at lambing in that flock is the factor contributing most to the losses. The cold, wet, and windy weather contributed to the death of 22 of the 25 lambs which died in exposed yards within three days of birth. Maternal factors and poor lamb vigour were also implicated but only in the death of eight lambs in each instance. Only one death occurred within three days in a comparable group of lambs which were removed from the ewes at birth and provided with food and warmth. None of the recognized infectious agents were implicated in any of the deaths.

14. BREEDING AND GENETICAL STUDIES.

(Division of Animal Health and Production.)

(*a*) *Inbred Flocks of Australian Merinos* (McMaster Field Station).—Inbreeding has been found to affect those characters associated with, or dependent on, the fitness of the animal. Body size, fertility, skin wrinkling, and fleece weight have declined as level of inbreeding increased. By comparison with non-inbred sheep, sheep having an inbreeding coefficient of 0.25 are 15 per cent. smaller, have a 33 per cent. lower wrinkle score, and a 12 per cent. lower greasy fleece weight. Lambing percentage of inbred two-tooth ewes was 11 per cent. in comparison with 40 per cent. for non-inbred ewes. Fleece characters not associated with fitness, viz. staple length, fibre diameter, fibre population per unit area, number of crimps per inch, and percentage clean scoured yield, appeared to be unaffected by inbreeding. In comparison with non-inbred sheep, inbred animals reach their peak in wool production one year later, and in reproduction, one to two years later.

(*b*) *Hornedness in Sheep* ("Gilruth Plains", Cunnamulla).—A choice has been made between the two hypotheses previously reported as explanations for the inheritance of hornedness in the Merino. Observations are most easily explained by a triple allele hypothesis. The dominant allele has the effect of producing depressions on the horn sites of females, and either depressions, short or long scurs, or aberrant horns on the horn sites of entire males. The intermediate allele results in the growth of true horns in the female and of the large curled horns characteristic of the Merino ram in the male. The recessive allele results in the growth of only a bone knob or short scur in the female, while in the male the horn growth produced is indistinguishable from that produced by the intermediate allele.

(*c*) *Strains of Merino Sheep in Several Environments* (McMaster Laboratory).—Analyses of the data have continued. The incidence of fleece rot in the strains suggests that inheritance has some influence on variation in this characteristic, but its contribution is small.

(*d*) *Project ABI.*—In one part of this project, progress through selection for clean wool weight is being checked against prediction in a flock of medium Peppin Merinos at "Gilruth Plains". After four years, the mean clean wool weight per head for 15-16 month-old progeny in the selected groups is 5 per cent. above the mean for progeny in the unselected groups, this gain being slightly above the prediction. Selection has been for maximum clean wool weight, with a control on fibre diameter and degree of wrinkling. Mean fibre number per square inch of skin and mean staple length are both much higher in the selected than the unselected groups, but the mean body weights are the same.

The second part of the project consists of eight pairs of groups, with selection for high and low values of single characters. Response to selection is marked in all cases and there is continued evidence of a lack of strong genetic correlation between some of the fleece characteristics. Staple length and fibre diameter appear in different combinations, for example, as do fibre diameter and crimp number. Degree of wrinkling and staple length, on the other hand, show a strong negative correlation.

During the year, rams from some of these paired selection groups were brought to the McMaster Laboratory for a test with measured feed intake. Six pairs of rams, from a total of three pairs of families, were included. The members of each pair were initially of the same body weight, but one had a high fibre number per square inch of skin and a high wool production per head, the other a low fibre number and low wool production. Over a period of four months on *ad lib.* feeding with a high-quality ration, the animals rated as "high producers" at "Gilruth Plains" ate the same amount per head per day as the "low producers", but gained 10 per cent. more per head in body weight and produced 25 per cent. more clean wool per head.

(*e*) *Interaction between Small Differences in Heredity and Large Differences in Environment.*—Following the termination of the strain trial, work has commenced on an experiment to investigate gene x environment interactions. Matings in two strains (fine non-Peppin and medium Peppin) took place at Cunnamulla in April, 1956, and were repeated at Armidale in May, with the same rams and two further groups of ewes of the same strains. The performance of the progeny of the same rams in two widely different environments will be compared.

(*f*) *Selection for Mutton Characteristics in the Merino.*—Experiments have been designed to determine the extent to which mutton characteristics can be improved in the Merino by selection, without sacrificing quantity and quality of wool.

(*g*) *Selection For and Against Twinning.*—Of the base ewes chosen for bearing twins in each of two preliminary years, 43 were present for the three subsequent years, and 22 (51 per cent.) of them bore at least two further sets of twins. Of the 36 chosen for bearing singles in each of the two preliminary years, 27 (75 per cent.) have borne singles in at least two of three subsequent lambings. Eleven ewes (25 per cent.) have now borne twins in each of five consecutive years, while 18 (50 per cent.) have borne singles in each of the same five years.

(*h*) *Electrolyte Concentrations of Erythrocytes.*—The determinations of K^+ and Na^+ concentrations of the erythrocytes of Merino sheep belonging to the AB1 and Strain Trial groups at "Gilruth Plains" showed that 5 out of 284 sheep had high (above 55 m.-equiv./l.R.B.C.) K^+ levels, 37 had medium K^+ levels (15-25 m.-equiv./l.), and the rest belonged to the "low K^+" group (5-15 m.-equiv./l.).

15. GENETICS OF SHEEP.

(Animal Genetics Section.)

A series of papers analysing data collected by H. B. Carter has been prepared for publication. The selection programme at Dickson continues. Studies of mozaic sheep indicate that at least three independent systems of determination of the fleece are operating: determination of wool production by density of primary follicles and their attendant follicle groups, determination of fibre dimensions by the number of follicles in the group, and a system relating fibre length to fibre diameter.

16. BIOLOGICAL STUDIES OF SKIN AND WOOL GROWTH.

(Division of Animal Health and Production.)

(*a*) *Endocrinology of Wool Growth* (Sheep Biology Laboratory). (i) *Wool Growth and the Anterior Pituitary Gland.*—Earlier work has shown that the anterior pituitary gland is necessary for normal wool growth. Work is continuing on the isolation and identification of the anterior pituitary hormones responsible for the maintenance of wool growth. Protein fractions of sheep pituitary extract have been prepared by continous zone electrophoresis, by low-temperature ethanol fractionation, and by ammonium sulphate salting out. Analytical electrophoresis has revealed up to 15 electrophoretically distinct proteins in sheep pituitary extracts. It has proved difficult to prepare these proteins free from contamination with one another. A preparation containing four proteins has been found active in restoring wool growth in the hypophysectomized sheep.

(ii) *Wool Growth and the Adrenal Cortex.*—Earlier experiments have demonstrated the inhibition of wool growth and the production of "break" by exogenous adrenocortical and adrenocorticotrophic hormones. A paper chromatographic method has been developed for measuring the concentration of cortisol in the peripheral blood of sheep. This method was developed to assess the role of the adrenal cortex in determining the productive capacity of sheep for wool growth under various environmental conditions. The sheep has been found to have a low circulatory level of cortisol compared with other species. The plasma clearance rate and the excretory pathways of cortisol and its conjugated derivatives in the sheep are being investigated, and measurements are being made of the blood-cortisol level under environmental conditions likely to be associated with increased adrenocortical activity. The blood level has been found to be elevated in pregnancy toxaemia.

(iii) *Wool Growth and the Thyroid Gland.*—Analysis of earlier results indicates that the increased food intake together with the nutrients supplied by the catabolism of body tissues fully accounts for the increase in wool growth observed following injections of sodium-L-thyroxine into adult sheep. No increase in the efficiency of conversion of food protein into wool can be expected from thyroxine administration.

(*b*) *Studies of Skin and Fleece Development*

(i) *Effects of Early Nutrition.*—Observations on the effect of nutrition during pre-natal and early post-natal life on the development of the follicle population and the juvenile and adult wool production of the sheep are continuing. Two features greatly complicated the experiment and have caused considerable delay in finalizing results. These are the extreme skin fold development in many of the animals, and evidence that many animals passed through a phase of shedding a proportion of primary follicle fibres at 12-15 months of age. This latter complication has necessitated carrying the observations on for a further period of 9-12 months in order to be certain that follicle development has reached a stable mature level.

(ii) *Histology of Skin of Sheep and Marsupials.*—Observations have been continued on the development of branching of wool follicles and of the epidermis and hair canals in the Merino foetus. A detailed histological study of skin samples from six adult Merinos has revealed several important features, including the presence of bundles of primary wool follicles, not previously described in sheep. A qualitative histological study of the growth and development of wool follicles from birth to maturity in Merinos and Southdown Merinos has been commenced. Observations on the development and replacement of pelage hairs in the bandicoot (*Perameles nasuta*), from birth to 526 days, have been completed. At birth, pelage hair follicles are absent, and the first follicles appear in the mid-lateral region of the trunk about eleven days after birth. The first hairs emerge in this region at about the 40th day, and at 48 days, most of the follicles of the first hair cycle have emerging hairs. The special features in the development and replacement of the hair follicles have been studied. Further studies have been made on the development of the skin and hair in the brush-tailed possum (*Trichosurus vulpecula*). The use of marsupials as experimental animals has enabled a concurrent study to be made of the post-natal linear dimensions and body weights of 181 specimens of *Trichosurus vulpecula*. Individual growth curves have been determined for some of these and a nomogram for age determination, based on twelve such individual records from birth to 200 days, has been constructed and used for obtaining information on the seasons of birth. Relative growth diagrams have been constructed and used to compare two isolated populations of *T. vulpecula*. The concept *linear equivalence* (cube root of the body weight) is introduced and used as a standard for studying the growth of the parts of the body and for making comparisons within and between species. In the present study, the growth of *T. vulpecula* has been compared with some higher mammals: man, cow, sheep, and mouse.

(iii) *Skin Grafting in Mice.*—It has been shown that with inbred lines, the incompatibility of male skin homografts in female hosts is not a universal phenomenon as has been accepted. Conditioning by injection of skin extracts and sequential homografting have failed to confirm overseas claims for abrogation of the homograft reaction.

(iv) *Lamb Birth Coat and Adult Fleece Characters.*—An extensive series of observations on the relationship of the lamb's birth coat to adult fleece characters has been completed in strong-wool South Australian Merinos. There was no relationship to body weight, clean wool weight, staple length, mean fibre diameter, follicle number per unit area of S/P ratio. There was a consistent relationship of lamb birth coat with variability of fibre diameter, increasing coarseness of the birth coat being associated with increasing variability and number of crimps per inch (coarse birth coats being associated with low crimp rate).

(v) *Physical Definition of "Doggy" Wool.*—Merino wool is considered to be "doggy" when it lacks a well-defined staple crimp, and any crimp-waves present are usually wider than those associated with "normal" Merino wool. "Doggy" wool often has rather straight fibres, and a lustrous appearance, but is different from the abnormality due to copper deficiency. Measurements are being made on samples of wool and skin from "normal" and "doggy" sheep in various strains of Merino sheep to compare the metrical characters of the samples.

(*c*) *Fleece Structure and Wool Production.*—The relation of density (number of wool fibres or follicles per unit area of skin) to wool production is of great practical importance in Merino sheep, and hence the study of this relationship has been approached from several angles. Preliminary results are in (i), (ii), (iii), (iv), and (v) of this sub-section. It is evident that the relation is a complex one and that its clarification will require much further study.

(i) *Follicle Density and Wool Production.*—The relationship of wool production per unit area of skin to follicle number per unit area has been investigated in flocks of strong-wool South Australian and medium-wool Peppin sheep. The correlation between these characters was positive but reached statistical significance only when large numbers were examined. The association was a little stronger in the medium-wool sheep than in the strong-wool sheep.

(ii) *Fleece Mosaics.*—This group now numbers 26 sheep which are being used to identify and investigate the determinants of wool production. Through measurement of the metrical characters of the fleece, the importance of area of fibre per unit area of skin and the length/diameter relationship of fibres has been demonstrated, e.g. area of fibre per unit area of skin can vary independently of density but it is an important determinant of wool production. Also, the length/diameter relationship of fibres, which is largely concerned with wool quality, appears to be independent of level of wool production per unit area.

(iii) *Fleece Mutants.*—Two families of fleece type mutants are being studied. One of these (low-density type) appears to be a simple genetic recessive while the other (lustre fleece type) appears to be a simple dominant. The lustre wool type is being extensively studied at both the Sheep Biology Laboratory, Prospect, and in the Wool Textile Laboratories. The physical behaviour of this wool is being studied under a variety of textile processes and in particular for its felting and frictional properties. These mutant types represent new combinations of the biological determinants of the fleece which allow comparative study of fleece structure and wool production. They have demonstrated a lack of genetic correlation between crimp and fibre diameter.

(iv) *Wool Production per Unit of Skin Area.*—A study of wool production per unit area on a number of body regions of ewes, rams, and wethers in different strains of Merino sheep, showed a marked variation from region to region. There was a distinct negative dorso-ventral gradient in wool growth per unit area, and smaller antero-posterior gradients. Sites on a line from mid-shoulder to mid-thigh had values close to the mean wool weight per unit area over the body. The mean wool production per unit area varied from sheep to sheep, and also from strain to strain. These differences were large, irrespective of the level of feeding. High correlations were found to exist between mean wool production per unit area and clean fleece weight, which indicated that wool weight per unit area can be used as an index of clean fleece weight in the selection of sheep.

(v) *Fleece Characters and Their Influence on Wool Weight per Unit Area of Skin.*—Considerable differences were found in staple length, fibre diameter, and number of fibres per unit area of skin, between two different strains of Merino sheep, as well as between sheep in each strain. The dependence of wool production per unit area on the fleece characters was also different in the two strains. Among medium-wool Merinos, fibre number had the greatest influence on wool production, although this influence decreased as wool weight per unit area increased. Among strong-wooled Merinos, length was the most important character, although fibre number had some influence when wool weights per unit area were relatively low. As wool weight per unit area increased, the influence of fibre number rose to a maximum and then decreased, at which stage fibre volume began to have a greater influence on wool weight per unit area between sheep. Staple length, fibre diameter, and fibre number were somewhat different in a number of regions over the body. Only fibre number showed any distinct negative dorso-ventral and antero-posterior gradients over the body. Fibre number had by far the greatest influence of the three fleece characters on the level of wool production of the various body regions for sheep in both strains.

(*d*) *Relation of Feed Intake to Wool Growth.* (i) *Efficiency of Wool Growth.*—Three groups of sheep, ranked as having high, intermediate, and low wool production per unit of body weight under field conditions, have been brought to the laboratory for detailed studies of wool production in relation to feed intake. One object of these investigations is to obtain indirect information on how much of the differences between sheep in wool production under field grazing is attributable to differences in feed intake. To study this aspect, the animals have been rationed according to body weight (60 g. per (kg. body wt.) $^{0\cdot73}$; ration, equal parts lucerne chaff and cracked corn). Only limited results are available at present, but there is strong evidence of a reduction of the differences in wool production under these feeding conditions.

(ii) *The Effect of Plane of Nutrition on Wool Growth.*—The metrical characters of the fleece are affected by changes in nutrition. Little information is available on the time required to establish equilibrium in the characters, when there has been a change from one feeding level to another. Accordingly, a group of eight sheep, which had been fed *ad lib.* from birth to two years of age, has been subjected to severe nutritional stress for eight months. The relative responses of the metrical characters of the fleeces are being investigated to establish the period required to reach equilibrium at a low level of nutrition.

(iii) *Feed Intake and Wool Growth of Grazing Sheep.*—Further analysis of data from an experiment designed to study differences in wool production between strains of Merino sheep has shown that the efficiency of wool production is significantly correlated with both clean wool production and clean wool production per unit of body weight. The data suggest, however, that although the election of sheep for clean wool production alone will esult in some degree of selection for efficiency, the use f clean wool weight per unit of body weight would be f greater value in selecting more efficient sheep. These ata have also shown that accurate comparative output of aeces by sheep over long periods can be obtained by aaking faecal collections over a 24-hour period each week.

(iv) *Utilization of Low-quality Roughages.*—Experiaents have been started to determine the physiological actors which limit the consumption, digestion, and utilizaon of low-quality roughages by Merino sheep.

(v) *Wool Growth and Protein Intake.*—This work has wo aims—firstly, to establish whether the upper limit of he sheep's capacity to grow wool is determined by the imit of its protein intake, and secondly, to examine the nfluence on wool growth of changes in protein intake uch as commonly occur in grazing sheep. To avoid loss f nitrogen due to deamination reactions in the rumen, rotein supplements (as casein) have been fed to sheep ia abomasal fistulae. Casein is virtually completely digested and absorbed when supplied at the rate of 20 g. nitrogen per day, at which level nitrogen retention was maximal; when still larger supplements of casein were given, nitrogen absorptions as high as 50 g. N per day were obtained.

(vi) *Interrelations of Fleece Components.*—Extensive data derived from a collection of skin samples taken from unclassed groups of maiden stud ewes of most breeds of sheep present in Australia, and from sire progeny groups in one Merino stud flock, have been analysed using the electronic digital computer (Silliac) at the University of Sydney. In particular, correlation and heritability studies indicate that number of follicle groups per unit area of skin is more closely related to wool production per unit area of skin than is total follicle density.

(*e*) *The Seasonal Cycle of Wool Growth.*—Earlier work has shown a close association between the mean air temperature and wool growth in sheep maintained on a constant food intake. The relative importance of air temperature and hours of daylight in producing this seasonal cycle is to be assessed in the climate rooms.

Adrenalectomized sheep maintained on a constant food intake and constant dosage of cortisone acetate and deoxycorticosterone acetate continue to show an association between wool growth and the mean air temperature. The association cannot therefore be attributed to the influence of air temperature on adrenocortical secretion.

(*f*) *Estimates of Fibre Number* (McMaster Field Station).—An attempt is being made to estimate fibre number per sheep as an alternative to fibre number per unit area of skin. As a preliminary step, ten fleece samples have been taken from each of ten sheep. They will be scoured and weighed and a sub-sample of fibres from each weighed and counted. Mean fibre weight will be determined. Immediately after sampling, the sheep were carefully shorn, and the fleeces weighed and scoured. It is hoped to assess fibre number per sheep from mean fibre weight and clean fleece weight. The sheep will be sampled and shorn at six-monthly intervals to determine repeatability of the method.

(*g*) *Crimp and Fibre Diameter Relationships.*—Accumulated data (1949-1954) from the inbred flocks were used in this study. Sheep were sampled at three points on the side—in front of the hip, at the mid side, and behind and slightly above the elbow. Over all inbred lines, and all years, fibre diameter was found to increase and number of crimps per inch to decrease with age. Diameter was least on the mid side and crimp number lowest behind the elbow. Correlations between crimp and diameter varied between sexes and between families, and were affected by inbreeding. Both crimp and diameter were greatly affected by season.

(*h*) *Fleece-rot.*—Data accumulated over a number of years indicate that there is a real, though low, heritability of susceptibility to fleece-rot under environmental conditions of moderate to high expectancy. There is also a very clear difference between several strains of Merino in susceptibility to fleece-rot. Fine wools are most resistant, and strong wools most susceptible.

17. Sheep Diseases.

(Division of Animal Health Production.)

(*a*) *"Toxaemic Jaundice" of Sheep* (Animal Health Laboratory, Melbourne).—*Chronic Copper Poisoning.*—Continuation of the studies on copper metabolism of sheep has revealed that, even under standard conditions, Merino sheep retain a smaller proportion of dietary copper than sheep of a British breed or its cross with the Merino; this substantiates reports from the field of the lesser susceptibility of the Merino to chronic copper poisoning. Following demonstration of the copper-molybdenum-sulphate interaction, it has been shown that the amount of sulphate required to make a given intake of molybdenum effective in limiting copper retention depends upon the protein content of the diet.

(*b*) *Copper Metabolism. Studies on Sheep in Western Australia* (Department of Agriculture, Perth).—An explanation is being sought for the occurrence of some very high liver copper values in sheep in the Toodyay area, where chronic copper poisoning had occurred in previous years. In the present investigation, liver copper levels have again been high but no disease has been manifest. Pasture samples have been analysed for copper, molybdenum, and sulphate content, and a search is being made for hepatoxic plants. Sheep and pasture samples from the Wiluna area are included in these studies; some of these sheep have been transferred to Bramley for further study in a copper-deficient environment.

(*c*) *Sheath Rot in Sheep* (Regional Pastoral Laboratory, Armidale).—An increase in the incidence and severity of chronic external ulceration of the prepuce and sheath rot (internal ulceration) in wethers in the New England region appears to be associated with grazing on improved, legume-dominant pastures. Sheath rot is rare on the largely non-leguminous native pastures, although external ulceration is common. A critical evaluation was made of the following treatments: surgical opening of the sheath, fasting, parenteral and topical use of procaine penicillin, topical application of 10 per cent. copper sulphur ointment, and removal of wool from around the preputial orifice ("ringing"). Only the surgical treatment gave satisfactory results; a single midline incision was just as effective as removal of a "V" shaped piece of skin. Fasting cured most cases temporarily, but the lesions soon recurred when the sheep were returned to sown pastures.

(*d*) *Mycotic Dermatitis* (McMaster Laboratory).—Numerous attempts have been made to isolate the causal organism *Nocardia dermatonomus* from samples of soil or pasture or from portions of the bodies of ewes on a property where lambs have been regularly and severely affected with mycotic dermatitis. The only source of infection found has been small residual lesions on the face and ears of ewes which hitherto were not recognized as those of mycotic dermatitis. As the organism grows readily in ovine amniotic fluid, it appears likely that lambs are infected by their mothers soon after they are born. Several field trials are in progress to investigate whether appropriate treatment of affected ewes lessens the incidence of mycotic dermatitis in their lambs. Some 800 ewes on four properties are included in the current investigations. In the first test conducted on ewes which lambed last spring, there was a striking reduction at marking in the incidence of early mycotic dermatitis in their lambs, compared with the lambs of control ewes. Unfortunately, dry conditions subsequently have prevented progress of the disease.

(*e*) *Footrot.*—Further screening tests for the treatment of footrot included the topical application of iodine, zephiran, petrol, 20 per cent. "Cetavlon" in alcohol, and a chloromycetin aerosol. Foot-bath treatments with 0.5 per cent. C.T.M.A.B., and 5 per cent. formalin plus 0.5 per cent. C.T.M.A.B., were also conducted. Of these chemicals, only the chloromycetin aerosol was highly effective under the conditions in which the tests were made. In the field, further experiments in wet winter conditions were conducted with an ointment containing 5 mg. terramycin and 10,000 I.U. polymyxin B sulphate per gram, and with 5 per cent. terramycin and 5 or 10 per cent. chloromycetin in methylated spirits. Of 23 feet treated with the ointment, 61 per cent. were cured after one application. Of 191 feet treated with 5 per cent. terramycin, 77 per cent. were cured after one treatment, whereas 67 per cent. of 50 feet treated with 5 per cent. chloromycetin responded. All of 24 feet treated with 10 per cent. chloromycetin were cured by one treatment. The results with terramycin were not as good as those achieved earlier in dry summer conditions.

Further bacteriological examination of cases of "scald" has been made. Although organisms resembling *F. nodosus* can be seen at times in smears from such cases, the organism has not been isolated in culture. With the cooperation of a grazier, some 8,000 sheep are being critically examined to test the ease with which carriers or persistent cases can be identified. The fundamental study on the growth requirements of *F. nodosus* is being continued. The organism failed to grow on the digested chemically pure proteins, fibrinogen, egg albumin, bovine serum, albumin, and insulin, either alone or in combination with or without 1 per cent. yeast extract. The value of digested prekeratin or wool keratin as a culture medium has been confirmed, and efforts are being made to determine the relative importance of the carbohydrate, protein, lipid, and electrolyte fractions. A qualitative analysis of the amino acid content of the digested prekeratin failed to reveal any particular features.

(*f*) *Foot Abscess.*—A study is being made at present in lambing ewes on a property subject to foot abscess to ascertain whether cracked or broken hooves predispose to the disease. The feet of 200 ewes have been trimmed, and a description has been taken of the state of the feet of another similar group. The incidence of foot abscess in these ewes will be recorded during the coming season.

(*g*) *Brucellosis of Sheep* (Animal Health Laboratory, Melbourne).—Serological methods of diagnosis have been further tested, but none, other than the complement fixation test, has proved to be satisfactory. Some cultural and biochemical examinations of the causal organism have been made, and inoculation tests have shown that some adult guinea-pigs harbour the organism in the spleen for as long as 50-70 days after intraperitoneal injection; in female guinea-pigs so injected, infection of the foetuses may result, the young being still-born or dying soon after birth.

(*h*) *Mortalities Off-shears* (McMaster Laboratory).—Instruments are being designed to record the clinical behaviour of shorn sheep exposed to artificial rain in a modified spray dip. This will enable measurements to be taken on several sheep simultaneously.

(*i*) *Enzyme Pathology* (McMaster Laboratory).—A study of the oxidation of fatty acids by brain mitochondria has been completed. Two enzymes of the fatty acid oxidation chain are virtually absent from brain and for this reason brain mitochondria do not oxidize fatty acids *in vitro*. Data have been compiled on the enzyme systems and enzyme catalysed reactions of the intermediary metabolism of normal sheep. An investigation of the biochemical aspects of the hepatoxic action of pyrrolizidine alkaloids has commenced.

(*j*) *Darling Pea* (*Swainsona spp.*) *Poisoning* (Regional Pastoral Laboratory, Armidale).—A survey of the extent and importance of the disease was made in the Warrumbungle district (New South Wales). Clinical and post-mortem descriptions of affected animals were recorded, and soil, plant, and animal specimens were collected for laboratory examination.

18. Internal Parasites.

(Division of Animal Health and Production.)

(*a*) *Studies on Anthelmintics* (McMaster Laboratory).—A phenothiazine derivative, 2-chloro-7-methoxyphenothiazine, which was highly efficient against oxyurid worms in mice, was not as effective as phenothiazine against *Haemonchus contortus*, *Trichostrongylus colubriformis*, and *Oesophagostomum columbianum* in sheep. Neither hexachlorethane nor phenothiazine was effective against *Ostertagia* spp., they were somewhat more effective when combined. Cadmium oxide (2.5 g.) given into the rumen was very effective against *H. contortus* and removed about 50 per cent. of *Oe. columbianum;* larger doses were fatally toxic. A mixture of piperazine hexahydrate and carbon tetrachloride was very effective against *H. contortus* and *Oe. columbianum* when given into the rumen. A mixture of piperazine hexahydrate and nicotine was effective against *H. contortus* and *T. colubriformis* when given into the abomasum. "Papain", the enzyme of pawpaw, was highly effective against *H. contortus* when given into either rumen or abomasum; against *T. colubriformis* it was ineffective when given into the rumen and showed variable effects when given into the abomasum; it was not effective against *Oe. columbianum* when given into the abomasum. The addition of a surface active agent, cetyltrimethylammonium bromide (C.T.M.A.B.) to nicotine sulphate slightly increased its efficiency against *T. colubriformis*. The addition of C.T.M.A.B. to 1 : 8-dihydroxyanthraquinone did not increase its activity against *T. colubriformis*. The addition of pyrimethamine did not enhance the anthelmintic activity of phenothiazine. Neither dieldrin nor dichlorophene was effective against *H. contortus* when given into the rumen. The stearate of the asymmetric complex tris-ethylenediamine Co(III) which was effective against oxyurids in mice did not show promise in sheep. An organic phosphorus compound, *O,O*-dimethylhydroxy-2,2,2-trichlorophosphonate, was highly effective against *H. contortus* and showed promise against *Oe. columbianum* but not against *T. colubriformis;* doses of 10 g. or more per 100 lb. body weight are likely to be toxic for sheep. Trials with oxyurid worms in mice showed that *O,O*-dimethylhydroxy-2,2,2-trichlorophosphonate and dichlorophene were very effective; 7,14-dithia-5,12-diazpantacine-6,13-quinone was not effective.

(i) *Phenothiazine-salt Lick* (Regional Pastoral Laboratory, Armidale).—A phenothiazine-salt lick was made available to groups of ewes grazed on sown pastures at two rates of stocking, four and eight sheep per acre. Over the summer of 1956-57, consumption of the lick (approximately 0.05 g. phenothiazine per head per day) was too low to have any anthelmintic effect. Worm-egg counts remained at a low level throughout the summer and no treatment differences due either to rate of stocking or to the phenothiazine-salt lick were observed.

(ii) *Piperazine.*—An experiment to study the effect of prophylactic doses of piperazine on the establishment of *Oesophagostomum columbianum* infestations in lambs has been commenced.

(*b*) *Fascioliasis.*—Preliminary figures from a survey based on liver condemnations at thirteen New South Wales abattoirs show that almost 20 per cent. of ruminant livers are lost through fascioliasis; 13.72 per cent. in 350,000 sheep and 48.72 in 65,000 cattle. An experimental fluke area of some 10 acres, established on a privately owned property some 100 miles from the laboratory, will be used for field studies of the bionomics of *Simlimnaea subaquatilis* and of the eggs and cercariae of *Fasciola hepatica*. The pathogenesis of fascioliasis in sheep is also under investigation. A high-output, even-coverage boom spray is now used for molluscicide spraying tests, with improved results. Copper pentachlorphenate has definite advantages over copper sulphate, but costs will probably be approximately the same for either compound. Parenteral administration of carbon tetrachloride has given encouraging results. Hexachlorethane and higher doses of carbon tetrachloride both kill most migrating flukes in sheep livers.

(*c*) *Epidemiology.* (i) *Field Observations.*—At the Regional Pastoral Laboratory at Deniliquin, sheep on irrigated pastures showed very light infestations and drenching with phenothiazine every second month had little effect on weight gains. A group provided with a 1 in 15 phenothiazine-salt mixture consumed it very irregularly, and the effect on worm burdens was negligible.

In Western Australia, worm burdens were very light in sheep in field trials and at Beverley there was no difference in performance between treated and control sheep. At Tarwongup, egg counts were generally lower than in previous years, and although monthly drenching with 1:8 dihydroxanthraquinone again gave remarkable control of *Chabertia ovina*, there were no great differences in weight between the sheep treated monthly with this compound, untreated controls, or those treated monthly with copper sulphate-nicotine sulphate.

At "Frodsley" in Tasmania, parasitological observations were made on ewes and lambs in a trial concerned with potash deficiency in pastures. Ewes showed rising egg counts in spring during lambing.

(ii) *Larval Populations on Sown and Native Pastures.* (Regional Pastoral Laboratory, Armidale).—In the final phase of this experiment worm-free lambs were grazed on sown or native pasture for two weeks and then held without further exposure to worm infestations for ten-twelve weeks before autopsy.

Nematodes recovered in appreciable numbers from lambs on both pastures throughout the year were *Haemonchus contortus, Ostertagia trifurcata, O. circumcincta, Nematodirus spathiger, N. filicollis, Trichostrongylus colubriformis, T. vitrinus, T. rugatus,* and *Trichuris ovis.* Other nematodes found irregularly and in small numbers included *Trichostrongylus axei, Oesophagostomum colubianum* (larvae), *Oe. venulosum, Dictyocaulus filaria,* and *Strongyloides papillosus.* The cestodes *Moniezia expansa* and *Cysticercus tenuicollis* were also found in some lambs.

The majority of the *Haemonchus contortus* were recovered, on both pastures, between December and March. *Ostertagia* spp., *Nematodirus* spp., and *Trichostrongylus* spp. were recovered at a fairly uniform rate throughout the year.

(*d*) *Resistance and Immunity to Nematode Infestation* (McMaster Laboratory).—When a challenge dose of *T. colubriformis* larvae was given to sheep which had experienced an earlier infestation, they often lost weight although no rise in egg count occurred and post-mortem examinations have shown heavy infestations with mature worms which were not producing eggs. Similarly, towards the end of an initial infestation, egg counts may decline but numerous worms may persist for some weeks and maintain unthriftiness in the sheep. When initial infestations were removed by drenching with phenothiazine and were followed by challenge does of larvae, it appeared that resistance increased with increasing duration of the initial infestation from four to eight weeks. Sheep challenged two weeks after treatment had removed the initial infestation were less resistant than those challenged eight weeks after treatment.

In a comparison of the behaviour of infestations with *H. contortus* and *H. placei* in sheep, there were no significant differences in pre-patent period, duration or degree of infestation, termination of infestation, response to challenge, the occurrence of "self-cure" when challenge doses of larvae were given, or in changes in circulating anti-bodies as detected by the C.F. test.

In a field trial at Cressy Farm, Tasmania, infestations with gastro-intestinal worm parasites increased in lambs from October, rose sharply from mid-February, and declined from mid-April. Challenge doses of *T. colubriformis larvae*, given to a new group of lambs each month, showed that lambs born in the spring may remain susceptible to this species until late in the following autumn in spite of a moderately heavy degree of natural infestation experienced. There were some indications that challenge doses of larvae given when lambs were eight-nine weeks old may stimulate the development of resistance.

At the Regional Pastoral Laboratory at Kojonup, administration of challenge doses of *T. colubriformis* larvae showed that lambs born in the winter months remained susceptible until the following autumn. Naturally acquired infestations were heaviest in February but did not exceed a total of 10,000 worms, chiefly *Ostertagia* spp. and *Trichostrongylus* spp.

(*e*) *The Exsheathment of Nematode Larvae.*—Exsheathment of infective larvae of certain nematodes parasitic in sheep has been shown to be dependent upon an extrinsic stimulus from the rumen. The active substance in the rumen is dialysable, and possesses optimum activity at about 40° C., and its function is inhibited by high oxygen tensions. Activity of the stimulus is related to the hydrogen ion concentration. For example, certain species exsheath in the rumen, whereas others will exsheath only in the abomasum, or in acidified rumen fluid. Larvae which have been activated by exposure to this stimulus produce an exsheathing factor which attacks the sheath and releases the larvae. This factor is inactivated by low hydrogen ion concentrations, by dialysis, by temperatures above 65° C., and by salts of mercury and lead. Homogenates of sheathed larvae are active without the presence of the extrinsic stimulus, and it seems possible that the function of the extrinsic stimulus may be to release a preformed exsheathing factor.

(*f*) Strongyloides papillosus.—Of eight anthelmintics tried against *Strongyloides papillosus*, only I.C.I. 16452 and gentian violet produced negative faecal egg counts, but results were erratic and some sheep died after dosing with the gentian violet. There were inconclusive results from soil spraying trials to control this parasite in sheep yards.

(*g*) *In vitro Screening Technique.*—Twenty-three anthelmintics are being tested against the free-living stages of *Haemonchus contortus, Ostertagia* spp., *Trichostrongylus axei, T. colubriformis,* and *Oesophagostomum columbianum;* their effects on *Strongyloides papillosus* have also been noted. About 60 essential oils or their principal constituents are also being tested against the free-living stages of *Haemonchus contortus.*

One hundred and twenty-five species of plants are listed as being used by the West African natives as anthelmintics; some species of the same genera are being collected by members of the staff of the Sydney Botanic Gardens, and extracts of them will be tested. The Sydney Technological Museum is also supplying extracts from eucalypts and tea trees.

(*h*) *Chemical Studies.*—The exsheathment factor for nematode larvae, present in the gastro-intestinal tract, has been concentrated. Synthesis of chlorinated phenothiazines by Smiles rearrangement has been thoroughly examined. The rearrangement cannot be used to prepare 7: 14-diaza-5: 12-dithia pentacene. Sulphur fusion methods gave uncertain products. Analytical techniques for phenothiazine and phenothiazone have been improved. The preparation of azaphenothiazines from pyridine amines is being examined. The Herz reaction on phenylene diamines gave unexpected products, and structural studies are being carried out. The toxicity of certain essential oils to nematode larvae has been correlated with the structures of certain of the constituents.

(*i*) *Chemical Composition of the Larval Cuticle.*—The amino acid composition and thermal behaviour of the sheath of the fourth stage larval cuticle of *N. muris,* and its reaction to proteolytic enzymes, acids, alkalies, and lyotropic reagents generally indicated a similarity between the protein of the sheath and collagen-like proteins.

(*j*) *Pathology of* Nippostrongylus muris *Infestation of the Rat.*—Morbid anatomy and water distribution previously reported have been completed to show that the small intestine is doubled in weight owing largely to an increase in the water content of both tissue and lumen. There is also a doubling of the width of the muscularis externa. Work is proceeding with the examination of electrolyte changes in the small intestinal tissue and contents, faeces, and plasma of infested rats.

19. EXTERNAL PARASITES.

(Division of Animal Health and Production.)

(*a*) *The Ecology of Ectoparasites.*—The study on the distribution of the eggs of mammalian lice on their hosts has been completed. It has been shown that the grooming behaviour of the host, the presence of fibres of suitable diameter to which the louse can attach eggs, and the presence of suitable temperatures are the main factors influencing egg distribution. A study of areas of the body which are suitable for louse multiplication has shown that skin temperature is the important factor. The eggs of all species of lice of cattle, horses, goats, and sheep which have been studied require temperatures between 30 and 40° C. for a period of ten-twenty days to hatch. Consequently, the extremities of these hosts are frequently unfavourable for louse multiplication during the winter months. At present a study is being made of the establishment of louse populations on clean hosts.

(*b*) Psorergates ovis.—During the year "patch tests" were used to gauge the efficiency of various insecticides against *Psorergates ovis,* the itch mite of sheep. This showed that certain organic phosphorus compounds, malathion, diazinon, and dipterex were promising at concentrations betwen 0.1 per cent. and 0.01 per cent. However, these concentrations border on the limit of economical usage. Field trials are in progress with malathion and diazinon. In preliminary trials under pen conditions, both these insecticides appeared to be efficient at concentrations of 0.001 per cent. against sheep body lice, and diazinon appeared to be efficient against keds also, at the same concentration.

(*c*) Ixodes holocyclus *Toxin.*—The nature and action of the toxin of *Ixodes holocyclus* and the nature of pink cuticular excretion have been investigated. Metabolic studies on tick infested mice have been continued and a technique for the artificial feeding of the ticks has been devised. The pink cuticular excretion of the ticks has been examined by paper electrophoresis in the pH range 1.5-12.0. The obtained pH mobility curve and pH fluorescence curve, the absorption curve of the compound, the effect of different ions on its fluorescence under u.v. light, &c., are in accordance with the supposition that it is a pyrrole pigment.

20. SHEEP BLOWFLY.

(Division of Entomology.)

(*a*) *Ecological Studies.*—Research has continued on the biology of the Australian sheep blowfly, *Lucilia cuprina,* by studying recaptured, marked specimens. Female flies were found to remain unfertilized for three days after emergence, despite a local abundance of males. Marked specimens have been recaptured a month after liberation, and one male six weeks after liberation. Flies of comparable or greater ages occur in the wild population, but are few in numbers.

In nature, as autumn advances, the egg batches laid by *Lucilia sericata* females are known to produce increasing percentages of diapausing larvae. This assures the survival of the species over the winter in the face of temporary reversion to mild weather. *Lucilia cuprina* has no corresponding mechanism, as the progeny of females of this species captured at intervals throughout April and May invariably completed their development in the same way as in summer. The mechanism of diapause production in *L. cuprina,* in fact, is not yet understood, though it is obviously not maternal-induced.

(*b*) *Oviposition and Mating.* (i) *Investigation of the "S Factor".*—Further experiments were carried out to determine whether there exists an "S factor", possessed only by living sheep, which accounts for the higher oviposition on living sheep near plugs soaked with indole and ammonium carbonate solutions than near plugs in clipped fleece. These confirm that the surface area of the fleece surrounding the plugs is the most important component of the "S factor"; the greater the area the greater the chance of females finding the plugs. Factors which appear to play no part are differences in carbon dioxide tension, moisture content, and temperature between the living sheep and the *in vitro* preparations. Movement of sheep does not attract flies to oviposit. Mouth and anal adours may have some significance.

(ii) *Group Oviposition.*—Females of *L. cuprina* often oviposit in groups. The formation of the groups has two causes. The females show a preference for ovipositing in cavities in the fleece, which are attractive as places of high moisture content and low illuminance. Females are also stimulated to lay by the presence of other ovipositing females.

(iii) *Relation between Mating and Ovarian Development.*—Only females of *L. cuprina* whose ovaries are fully developed or nearly so will willingly accept attempts at copulation.

21. OTHER SHEEP INVESTIGATIONS.

(Division of Animal Health and Production.)

(*a*) *Clover Oestrogens* (Department of Agriculture, Perth).—Techniques for the extraction of clover chloroplasts prior to assay have been improved; further assays of fractions have been made by the Chemistry Department of the University of Western Australia.

(*b*) *Phalaris Staggers* (Regional Pastoral Laboratory, Armidale).—A hypothesis that the sudden death or staggers syndromes in sheep grazed on phalaris-dominant pastures might result from derangement of mineral metabolism was examined. No cases of phalaris staggers occurred in Romney Marsh or Merino weaners grazed on a phalaris-dominant pasture, but a decline in serum magnesium was associated with a marked increase in the level of rumen ammonia. This association was not affected when sheep were drenched with cobalt. Similar results to those obtained on the phalaris-dominant pasture were observed in sheep on a clover-dominant pasture.

The work of the Division of Biochemistry and General Nutrition on phalaris staggers is reported in Section 7 of this Chapter.

VIII. CATTLE.

1. GENERAL.

If Australia is to maintain both its own food standards and an export of meat and dairy products on the pre-war level, research must find means to enlarge the entire cattle industry. Products of the cattle industry—meat, hides, and dairy produce—represent over 20 per cent. of all Australian rural production. The Organization has made a broad approach to the problems of this field, first instituting a survey of the structure and interrelations of the various sections of the beef cattle industry throughout Australia. Investigation at work now comprises the following: the elimination of loss from disease in both beef and dairy cattle; improvement of nutrition by the development of sown pastures; better management of natural pasture; development of systems of breeding designed to evolve more productive beef and dairy types for northern Australian conditions.

The Organization's work on cattle problems has been carried out chiefly by the Division of Animal Health and Production, mainly in the Animal Health Laboratory in Melbourne, the National Cattle Breeding Station at "Belmont", near Rockhampton, Queensland, and the Veterinary Parasitology Laboratory in Brisbane, Queensland (see Sections 2, 3, 4, 6, 7, and 8 of this Chapter). The Division of Entomology has been concerned with work on the cattle tick (see Section 5 of this Chapter). The work of the Division of Plant Industry on pastures is also of great importance to the cattle industry (see Chapter III.). The work of the Animal Genetics Section on beef cattle is described in Section 9 of this Chapter.

2. CATTLE DISEASES.

(Division of Animal Health and Production.)

(*a*) *Pleuropneumonia of Cattle* (Animal Health Laboratory, Melbourne).—Work was again concentrated upon problems associated with vaccination and immunity. It was found that after tail inoculation, the organism may appear transiently in the peripheral blood during the first two hours, and it is considered that this is the phase when opportunity for localizing in the joints of young calves occurs. Further evidence was obtained that local tail reactions and complement fixation (CF) reactions occur much less frequently in calves 5-9 months old than in adults, and the immunity of such calves will now be challenged. The adjuvant effect of agar was confirmed; with standard vaccine diluted 1 : 2000, no tail reactions and only 7 per cent. of CF reactions occurred in 30 adult animals, whereas when this was combined with 0.5 per cent. agar, 13 per cent. of tail reactions and 58 per cent. of CF reactions were observed. The possible value of dead (formalin-killed) vaccine is being examined, to determine whether it can give rise to effective immunity, and whether its prior use can reduce the likelihood of "bad-tail" reactions following inoculation with living vaccine. A group of 22 pairs of identical twins is under experiment to obtain information on the importance of genetic constitution on "bad-tail" reactions, on capacity to develop effective resistance, and on susceptibility to experimental pleuropneumonia. Some of these animals which developed "bad tails" were used for chemotherapeutic experiments. Terramycin has shown advantages over chloromycetin, since it was regularly and quickly followed by negative blood cultures. Further experience with the whole-blood slide agglutination test in a field outbreak again demonstrated its value. Much attention was given to freeze drying of vaccine in an attempt to improve survival. A potency check demonstrated that the "V5" strain is still satisfactory for producing vaccine. During the year, 790,550 doses were issued and CF antigen was donated to governmental authorities in Australia, Kenya, and the United States of America.

(*b*) *Brucellosis of Cattle.*—The long-term experiment on the duration of immunity, following strain 19 vaccination, has been concluded. The results accord with those of other investigators who found no practical advantage in revaccination. Some animals were so susceptible to infection that they did not withstand a first challenge during pregnancy; not all of these very susceptible cattle aborted, but they were excreting virulent *B. abortus* at the time of normal calving, and this indicates the risk of maintaining infection through the presence of such inapparent "spreaders" in a vaccinated herd. Those cattle which resisted the first challenge had a lengthy period of immunity, some remaining immune after challenge in seven successive pregnancies; in each of these challenges, a suitable control group showed an abortion rate of about 50 per cent., and often a total of 70-90 per cent. were excreting virulent *B. abortus* at parturition, whether that were an abortion or a normal calving.

Many valuable incidental data have been collected from the examination of specimens from control and vaccinated cattle during this investigation. When collated, it should be of considerable assistance to authorities exercising control or eradication measures in the Australian environment.

(*c*) *Haematuria Vesicalis of Cattle.*—The examination of tryptophan metabolites appearing in the urine of mice under different dietary conditions has been made in continuation of the study of possible bladder irritants.

The methods developed are being used in the study of ruminant urines.

(*d*) *Infertility in Dairy Cattle.*—In the continued study of herd infertility in some dairy cattle in Victoria, it has been found that vibriosis is the more common cause than trichomoniasis. Fifty herds proved negative in tests for trichomoniasis, but 21 of 30 tested for vibriosis showed evidence of being affected. The existence of vibriosis in Tasmania has also been established. Intensive examinations of a few herds have emphasized the difficulties often experienced in trying to isolate the organism in order to make the diagnosis certain. In a bull, known to be transmitting infection with *Vibrio fetus*, which is a catalase-positive organism, repeated examinations revealed only a vibrio morphologically similar, but catalase negative; this catalase-negative vibrio could not be recovered after test mating with virgin heifers but *V. fetus* was recovered.

Cattle have been used experimentally in the study of the transmission of vibriosis and for cultural and serological examinations after infection. Guinea pigs which were inoculated intraperitoneally with *V. fetus* culture aborted infected foetuses, but attempts to reveal the presence of the organism by injecting preputial washings and semen or vaginal mucus from naturally infected cattle failed.

(*e*) *Copper Metabolism Studies on Cattle in Western Australia (Department of Agriculture, Perth).*—Experimental cattle are being depastured on the copper deficiency area at Bramley; appropriate estimations of the copper content of body tissues and fluids will be made, and more intensive work on chemical pathology and histopathology will be undertaken when clinical manifestations of hypocuprosis are judged to be imminent.

(*f*) *Bloat in Beef Cattle* (Regional Pastoral Laboratory, Armidale).—The value of free-choice peanut oil for the control of frothy bloat in cattle grazed on phalaris-clover pastures was investigated. Oil was added to the drinking water in one treatment and to the drinking water and a hay supplement in a second treatment. Both treatments reduced the incidence and severity of bloat, but two of fifteen animals in each group died from bloat.

3. INTERNAL PARASITES.

(Division of Animal Health and Production.)

The following investigations were carried out by the staff of the Veterinary Parasitology Laboratory, Yeerongpilly, Queensland:—

(*a*) *Parasitic Gastro-enteritis of Cattle* (i) *Susceptibility of* Bos taurus *and* B. indicus *to Helminth Infestation.*—Investigations commenced in 1956 at the National Cattle Breeding Station, "Belmont", Queensland, have been continued. The first year's trial indicated little, if any, differences in levels of infestation with *Cooperia, Oesophagostomum,* and *Bunostomum,* in groups of Hereford, Hereford x Zebu, and Hereford x Afrikander calves. The infestations with *Haemonchus* were heaviest in the Hereford group, and lightest in the Hereford x Afrikander. The 1956 calf drop is now entering the experiment.

(ii) *Epidemiology Trials.*—Calves reared worm free are being exposed at regular intervals at Amberley Field Station to a pasture heavily seeded with helminths. Regular egg counts, body weights, and pasture analyses are being made in an attempt to correlate these with weather conditions and pasture larval counts, and also with worm counts from calves which appear to differ in susceptibility to infestation.

(iii) *Ecology of the Preparasitic Stages of Cattle Strongyles.*—Investigations into the development, migration, and survival of larvae under natural conditions have been continued. Results again suggest that summer temperatures may be lethal to developing larvae (*H. placei* and *Cooperia* spp.) in cattle pats. The highest temperatures recorded in pats during December was 122° F. with a solar radiation maximum of 170° F. In the laboratory, temperatures of 108° F. were unfavourable to larvae after 4 hr. exposure, the first and second stage larvae being most susceptible. Although complete development can occur in a pat in the absence of rain, evidence is growing that larvae (*H. placei* and *Cooperia* spp.) may not move on to the pastures in any numbers until stimulated to do so by rain. Young larvae appear more active than old larvae and tend to migrate further. Larvae in the field (April-July) may remain infective to calves for at least three and one-half months.

(iv) *Recovery of Strongyle Larvae from Soil and Vegetation.*—A new technique has been developed which relies on an upward current of water to free larvae from debris; they are trapped and recovered from the washings in a fine sieve. Critical tests have given an average recovery rate of about 80 per cent.

(v) *The Role of Copper in Parasitic Gastro-enteritis.*—Faecal egg counts, body weights, haematology, and blood and liver copper levels, are being followed in two groups of calves grazing a copper deficient pasture. One group receives intravenous copper supplementation. After six months, the mean liver copper values were 102 p.p.m. in the supplemented group and 10 p.p.m. in the control group. No differences have yet been detected in body weights or worm egg counts.

When stall-fed Shorthorn calves were exposed to severe infestations with hook-worm (*Bunostomum phlebotomum*), minimum haemoglobin levels of 3-4 g. per cent. were reached nine to ten weeks after infestation. Whole-blood and plasma copper levels were also depressed. As serum protein levels were considerably lowered, the depressed blood copper levels may have resulted from an insufficiency of circulating proteins responsible for copper transport. Liver copper levels of the infested calves had fallen from 210 p.p.m. to 149 p.p.m. in twelve weeks, whereas the levels in the uninfested controls had risen from 213 p.p.m. to 225 p.p.m. Hook-worm infestation therefore may play a minor role in the production of low liver copper levels on pastures which provide only a marginal copper intake. A further trial to check these findings is in progress. Estimations are being made of the concentration and distribution of copper in various species of helminths and of the possible effect thereon of different levels of dietary copper intake by the host.

(vi) *Paramphistomes of Cattle.*—*Pygmanisus pelorius,* the planorbid vector of the rumen fluke *Calicophoron calicophorum,* was found in depressions or "melon holes" at Amberley Field Station, 24 hr. after these had been filled by rain. During very wet periods when the melon holes overflow and the whole area is covered by water, these snails could be collected from any part of the flooded areas. When the melon holes had been dry for three months, samples of turf up to 5 inches in depth revealed the presence of many live snails, some of which contained well-developed rediae morphologically similar to those of *C. calicophorum.*

(vii) *Anthelmintics.*—At a dose rate of 0.3 g. per 100-lb. body weight, piperazine hydrate proved effective against *O. radiatum,* and at 0.5 g. per 100-lb. body weight, also against *Ostertagia.* At these levels, it had little effect on *Haemonchus, Cooperia, Bunostomum,* and *Trichostrongylus.* Premedication with sodium bicarbonate to ensure reflex closure of the oesophageal groove did not increase its efficiency. At dose rate of 10 and 20g. per 100-lb. body weight given by mouth, polymeric piperazine-1-carbodithioic acid ("Safersan") was effective only against *O. radiatum.* When injected directly into the abomasum at the higher dose rate, it gave good results in the three calves on which it was tested against *Haemonchus, Cooperia,* and *Oesophagostomum.*

Toluene, when given by mouth at a dose rate of 10 ml. per 100-lb. body weight, as an emulsion following premedication with sodium bicarbonate, proved highly effective against *Haemonchus, Bunostomum,* and *Cooperia.* It appeared promising also against *Trichostrongylus* and *Ostertagia,* but the infestations were slight. Overnight starvation was found to be essential for efficacy. In therapeutic doses, toluene was relatively non-toxic and, at most, was responsible for temporary anaesthesia and some inappetence. No abnormalities in the concentration of red blood cells or in white blood cell counts were noted, and no changes were observed in the liver. Xylene and tetrachlorethylene given as emulsions also showed evidence of high efficiency against the species mentioned.

At a dose rate of 2 g. per 100-lb. body weight, 1 : 8 dihydroxyanthraquinone was highly effective against *Haemonchus, Cooperia,* and *Oesphagostomum.* At this dose rate, the drug was non-toxic, but doses of 4-5 g. per 100-lb. body weight caused severe purging and inappetence for about 48 hr. Premedication with sodium bicarbonate was unnecessary.

Six organic phosphorus compounds were also tested. DDVP, diazinon, chlorthion, Bayer "L21/199", and malathion showed little or no anthelmintic effect in limited tests, but Bayer "L13/59" (*O, O*- dimethyl-2, 2, 2-trichloro-1-hydroxyethyl phosphonate) proved highly efficient at a dose rate of 2 g. per 100-lb. body weight against *Haemonchus, Ostertagia,* and *Oesophagostomum.* At 5 g. per 100-lb. body weight, it removed all *Bunostomum* and a high percentage of *Cooperia.* At this dose rate, it is also proved effective against four-eight- and fourteen-day-old *Haemonchus* and *Cooperia,* fourteen-day-old *Oesophagostomum,* and fourteen- and 28-day-old *Bunostromum.* At dose rates up to 3 g. per 100-lb. body weight, Bayer "L13/59" showed no toxic effects, although there was some temporary decrease in red cell cholinesterase activity. However, in view of the depressing effect of organic phosphorus compounds on blood levels of cholinesterase, further studies are required to ascertain whether safe levels of dosage, and of intervals between doses, can be determined.

4. CATTLE TICK.

(Division of Animal Health and Production.)

(*a*) *Susceptibility to Infestation of* Bos taurus *and* B. indicus.—These studies, now in their third year at Yeerongpilly, have confirmed that Zebu x Shorthorn cattle are more highly resistant to infestation than pure Shorthorns of comparable age. Differences in the degree of resistance continue to be apparent, and in some of the crossbreds infestations have approximated those of the more resistant animals among the purebreds.

When exposed to natural infestations, the Shorthorns had to be treated four times within a period of five months to control their infestations, whereas on no occasion was it necessary to spray the crossbreds. Weekly observations on these animals will be continued for another year.

(*b*) *Laboratory Hosts for* Boophilus microplus.—The advantages of a small animal as a laboratory host for research on the cattle tick are obvious. It has been found that this tick will readily mature on the head and ears of white mice to which an Elizabethan collar is attached to prevent the removal of the parasites by scratching. Larvae engorge on mice in five-seven days, nymphs in seven-nine days, and adults in fifteen-seventeen days, giving a total parasitic life cycle of 23-29 days. These periods are very similar to those for ticks engorging on cattle. The yield from the mice has not been great, the highest mortality being in the nymphal stage. The engorged females from the mice were smaller than those from cattle, having an average weight of 0.065 g. (0.033-0.101 g.) compared with an average weight of 0.232 g. from Shorthorns and 0.161 g. from Zebu x Shorthorn. The females from the mice, however, laid viable eggs and the larvae appeared to be normal. It is of interest that larvae on mice engorge partly, if not wholly, on blood whereas on cattle they do not ingest blood. The suitability of other laboratory animals as hosts for *B. microplus* is being explored.

(*c*) *Tick Toxins.*—Studies with electrophoretic techniques for the identification of the toxins in tick eggs have been continued. The toxic fraction previously designated ixovoglobin has been examined spectrophotometrically. Its absorption characteristics have been defined and its prosthetic group identified as belonging to the haematin class.

(*d*) *Host Resistance.*—Evidence has been obtained that the mechanism of resistance to tick infestation by cattle is a hypersensitivity reaction and that it is associated with an increase in the number of mast cells in the skin. A suitable technique for the fixation and serial sectioning of bovine skin to permit the closer study of mast cells has been developed.

(*e*) *Tick Fevers.*—Research has commenced which aims at elucidating the life-cycles of the protozoal parasites of " tick fever " in the tick and in cattle. Studies on the epidemiology of tick fever will also be undertaken. A strain of " clean " ticks has been obtained. These are being dissected and sectioned for anatomical study and searched for organisms or structures which could be confused with stages in the life cycle of tick fever protozoa.

(*f*) *The Cytology of Ixodid Ticks.*—The chromosome numbers of both *B. microplus* and *Ixodes holocyclus* has been determined as $2n = 21$ (male), 22 (female). The X chromosomes of *B. microplus* are readily identified by their large size, but those of *I. holocyclus* cannot be distinguished from the autosomes. Meiosis in the males of both species displays no unusual features.

The chromosome number of *Haemaphysalis bispinosa* has been tentatively estimated to be $2n = 31$ (male), 33 (female). The seminal vesicles of 12 engorged *H. bispinosa* females collected from range cattle were examined for sperms but none was found. Twelve similar females were incubated and all laid viable eggs. Experimentally reared females, which had never been in contact with males, engorged normally and laid viable eggs. Further evidence that this species exhibits facultative, if not obligatory, parthenogenesis was given by the only two males reared experimentally, neither of which contained sperms.

(*g*) *Tick Identification.*—Identification of tick specimens continues to be made for various institutions in Australia and overseas.

5. BIOLOGY AND CONTROL OF THE CATTLE TICK.

(Division of Entomology.)

Further research has been carried out on the resistance of ticks to acaricides, the mode of action of toxicants, and the screening of substances as potential acaricides. Contributions have also been made in the ecological approach to the problem of cattle tick control, as exemplified by the successful use of pasture spelling.

(*a*) *Acaricide Resistance.*—The degree of resistance to DDT (alone among chlorinated hydrocarbons used for tick control) has remained sufficiently low to enable control to be achieved by dipping more frequently at higher concentrations. Further results obtained with organic phosphorus acaricides against ticks resistant to chlorinated hydrocarbons have not been as satisfactory as those obtained at first, and some members of this group of chemicals achieve varying degrees of control at each successive treatment. One strain of ticks resistant to dieldrin and toxaphene showed heightened tolerance to an organic phosphorus compound, but this was believed to reflect vigour tolerance rather than organic phosphorus resistance.

Further investigations with a DDT-resistant strain of *Boophilus microplus* indicated that DMC and DME produce an augmented effect of DDT against DDT-resistant ticks principally by decreasing egg viability rather than increasing tick mortality.

" Kelthane " (1,1-bis(chlorophenyl) trichloroethanol) is a DDT-type molecule which cannot be dehydrochlorinated, and if DDT resistance depends on enzymatic dehydrochlorination, " Kelthane " should be equally toxic to DDT-susceptible and DDT-resistant ticks. Preliminary tests have indeed suggested that this is so, and, if confirmed by further work, this will afford support for the suggestion that DDT resistance in ticks is due to dehydrohalogenation of DDT to a non-toxic molecule.

(*b*) *Investigation of Factors Possibly Affecting Toxicity of Acaricides.* (i) *Effect of Formulation on Penetration and Toxicity.*—Particle size has been suggested as an important factor in the toxicity of DDT suspensions. Laboratory trials, however, demonstrated no marked differences in the toxicity of DDT to ticks, whether the DDT was prepared as a colloid, or as a crystalline suspension, nor was any difference found in these experiments in the amounts of DDT penetrating into the ticks.

Colloidal DDT suspensions prepared with different emulsifiers were found to exhibit little variation in their toxicity to ticks.

(ii) *Influence of Post-treatment Temperatures on Toxicity.*—After DDT-susceptible adult female ticks were either dipped in a DDT suspension or injected with DDT, it was found that the DDT was 13 times more toxic when the ticks were stored at 20° C. than at 30° C. When DDT was injected into DDT-resistant adults it was approximately six times more toxic at the lower temperature. Dieldrin and toxaphene, on the other hand, were less toxic at 20° C. than at 30° C., but diazinon was equally toxic at both temperatures.

(*c*) *Dipping and Spraying Formulations.* (i) *Insecticide Deposits on Animal Fibres.*—When it was found that the amounts of dieldrin remaining on the hair of cattle increased with each successive dipping, it was thought that this might indicate progressive accumulation of the toxicants. Analyses of hair samples taken between dippings during trials with dieldrin and aldrin in dips showed that scarcely any dieldrin or aldrin was detectable immediately before succeeding dippings were carried out, so that progressive accumulation is ruled out.

Diazinon is generally rapidly lost from cattle hair, having disappeared almost completely, for instance, three days after spraying with 0.05 per cent. diazinon. By contrast, on sheep diazinon treatment exerts effects on parasites for long periods. A chemical test also suggested its presence in the wool of sheep many weeks after spraying with 0.02 per cent. diazinon. After some of the wool from these sheep was exhaustively extracted with organic solvents, the wool still remained toxic to blowfly larvae, but it lost its toxicity when extracted with water. The possibility exists, therefore, that the persistent toxicity associated with diazinon on sheep is due rather to a water soluble derivative not detected by the chemical test.

(ii) *Diazinon in a Dipping Vat.*—Diazinon was tested in a dipping vat at concentrations from 0.05 to 0.10 per cent., and, even though chemical analyses indicated that the diazinon remained stable, the toxicity to ticks was disappointing. A mixture of diazinon and DDT, however, gave very satisfactory results.

(iii) *Bayer "L13/59".*—Trials with this organic phosphorus material over the last season gave results inferior to those described in the previous report.

(iv) *Bayer "21/199".*—This organic phosphorus material has given good control of ticks at concentrations as low as 0.05 per cent. Protective periods ranged from seven days at 0.05 per cent. to nine days at 0.25 per cent.

(v) *Other Substances.*—The following substances were tested as sprays on cattle and found to offer little promise as acaricides: 1 per cent. DDVP (dimethyl dichloro vinyl phosphate), 0.1 per cent. "HOE 2675", and 0.05 per cent. "Dow ET-57" (organic phosphorus compounds), and 1.0 per cent. "Perthane" (diethyl diphenyl dichloroethane).

(*d*) *Systemic Acaricides.*—A simpler and more economical method of screening potential systemic acaricides has been investigated. This involves the use of the three-host tick, *Haemaphysalis bispinosa,* on laboratory rabbits. The injection of lindane, dieldrin, and aldrin into rabbits gave results against *Haemaphysalis* similar to those reported previously with *Boophilus* on cattle.

A number of compounds administered to bovines showed no particular promise as systemic acaricides.

(*e*) *Pasture Spelling Experiments.* (i) *Carefully Controlled Experiment.*—Quantitative weekly comparisons of the infestations of cattle from continuously stocked and spelled paddocks have continued at Amberley, the treatments having been reversed in January 1957. During the latter half of 1956 the herd on continuously stocked pasture was moderately to heavily infested during every month except October, and had to be treated with DDT in June and November because of excessively heavy infestation. The "pasture spelling" herd continued with very light, or undetectable infestations, without any acaricidal treatment.

(ii) *Large-scale Field Experiments.*—The trial at Calliope (central Queensland) has been modified to allow more acres per head in winter than in summer. Tick infestations remained low on the "pasture spelling" herd, with dippings in July (for lice) and November 1956, and January and April 1957.

At Townsville progress has been made in excluding stray infested cattle from experimental paddocks, and improving acaricidal treatment of the cattle before they enter the spelled paddocks, with the result that their infestations have been reduced to a low level.

(iii) *Survival of Larvae.*—When cattle are removed from an infested pasture the tick larvae gradually die out, and the rate at which this occurs can be studied with a device which is pushed through the pasture, the larvae clinging to cloth surfaces provided. Sampling carried out every fortnight on a randomized layout showed that larval numbers fell more rapidly than expected, very few being picked up six weeks after the vacation of a paddock in mid-January.

(iv) *Survival of Ticks Dipped in DDT.*—Engorged ticks treated with 0.5 per cent. *pp'*-DDT lost water more quickly and produced fewer eggs and larvae than untreated ticks at R.H. 80 per cent. or lower (30° C.). Batches of DDT-treated and untreated ticks are being exposed in the field to record production of larvae at different times of the year. The results could influence decisions on whether cattle should be treated once or twice with DDT before entering spelled pastures.

6. INVESTIGATIONS WITH DAIRY CATTLE.

(Division of Animal Health and Production.)

(*a*) *Nucleus Herds of Sindhi and Sahiwal Cattle* (McMaster Field Station).—The foundation stock for these herds have been moved to the McMaster Field Station, Badgery's Creek. As a result of artificial insemination of Jersey females from the Sindhi and Sahiwal bulls, there are 16 F_1 male and 11 F_1 female calves. Now that the Pakistani bulls are at Badgery's Creek, they will be paddock mated to the Jersey herd.

(*b*) *Coat Shedding Studies.* (i) *Observations on Sindhi and Sahiwal Cattle.*—Preparation and examination of skin biopsy material from these cattle have been completed. There are two shedding periods—autumn and spring. Spring shedding is the major and more dramatic event, virtually the whole coat being replaced. Examination of hair samples, taken concurrently with the skin biopsy samples, has still to be completed.

(ii) *Growth and Development Studies with Calves.*—Hair and skin biopsy samples are being collected monthly from five female F_1 calves born in the Zebu-cross dairy herd, and five purebred Jersey calves of the same age. Collections will continue until the animals reach two years of age, and changes in the coat due to increasing age will also be studied.

(iii) *Shedding and Plane of Nutrition.*—This experiment is now in its second stage, treatments applied to the two groups of cattle (*ad lib.* feeding and submaintenance feeding) in 1956 having been reversed. The cattle on a low plane of nutrition grew a heavier, longer winter coat than those which were well fed. Although their coats loosened at the same time in the spring, they took several weeks longer to shed.

(*c*) *Sweat Gland Studies.*—Sufficient exercise to produce a considerable increase in rectal temperature and patent sweating caused a reduction in sweat gland volume of approximately 20 per cent. in both Zebu x Jersey crossbred and purebred Jersey cattle. A hot box is in course of construction so that effects of stress due to known heat increments may be studied. Sweat gland volume was measured on skin biopsy samples from the Sindhi and Sahiwal cattle taken at monthly intervals for twelve months. Distribution of mean sweat gland volume from these monthly samples was in the shape of a curve, with a peak in midwinter and a trough in midsummer.

7. BEEF PRODUCTION IN AUSTRALIA.

(Division of Animal Health and Production.)

Items (*a*), (*b*), (*c*), and (*d*) have been the activities of the William McIlrath Fellow in Animal Husbandry, with head-quarters at the McMaster Laboratory.

(*a*) *Investigations in the Southern States.*—These investigations have been continued in collaboration with the Departments of Agriculture in New South Wales, Victoria, South Australia, Western Australia, and Tasmania. Data on the growth performance of grazing cattle in a wide range of environments have been collected and published.

Data have been obtained on the growth of cattle given supplements of hay, concentrates, or green feed crops such as oats or choumoellier. Complete hand feeding experiments have provided comparative data on the performance of cattle fed on high and low roughage rations, various concentrate mixtures, weathered hay, silage, roughages fed ground or long, and the influence of small supplements of diethylstilboestrol. Comparative breed and environmental data on growth rates and on subjective and objective carcass appraisal measurements have also been collected. Sire production data have been obtained at one centre.

(*b*) *Feeding Stud Cattle.*—Complete nutritional and liveweight data have been collected from two Hereford studs.

(*c*) *Vitamin A Requirements.*—Vitamin A and carotene analyses have been carried out on serum samples collected from cattle in the coastal region of Queensland and from cattle on the C.S.I.R.O. Research Station at Katherine, Northern Territory. At Katherine, samples of serum collected during November 1956 assayed 16.2 ± 4.1 and 51.7 ± 24.8 μg. per 100 ml. for vitamin A and carotene respectively. Corresponding values for samples collected in October 1956 at Collinsville, Queensland, were 28.6 ± 6.8 and 1330 ± 425 μg. per 100 ml.

(*d*) *The Use of Antipyrine to Measure Body Water.*—Studies on the antipyrine techniques for estimating body water *in vivo* have been extended to include rabbits and goats as experimental animals. In rabbits, close agreement has been obtained in *in vivo* and *in vitro* estimations of body water, the results indicating that antipyrine can be used successfully with rabbits for body water estimations *in vivo*. The relationship between percentage of body water (x) and body fat (y) of the rabbit has also been studied and found to be $y = 94.38 - 1.28x$. The percentage water content of the lean body mass was found to be 72.8 ± 1.35. The results of experiments with goats have been less conclusive.

(*e*) *Environmental Control of Coat Changes in Cattle* (University of Queensland). (i) *The Role of Nutrition.*—The normal coat shedding of three of four undernourished Shorthorn heifers, in response to lengthening daylight, was impeded, and the retained hair coat was lustreless and bleached. The fourth animal shed its coat normally. Two of four similar animals in a well-fed group partially retained the winter hair coat during summer, but it was of normal colour and lustre.

(ii) *Effect of An Equatorial (Constant) Photoperiod on the Coat Cycle of Cattle.*—Thirteen European cattle have been maintained for periods of up to 21 months in a light environment simulating the equatorial photoperiod. Transfers in the spring and autumn were followed by complete shedding; those in winter by a rapid partial shed, and those in summer by rapid growth of hair. On settling down in the new environment, however, all groups eventually grew, and thereafter permanently maintained a similar coat, characterized by intermediate length and furry appearance, which would tend to heat retention.

(*f*) *Effect of Coat Length on Heat Tolerance of Cattle.* (i) *Seasonal Change in Heat Tolerance of Cattle.*—Four Shorthorns and one Zebu were tested for heat tolerance at monthly intervals in a standard atmosphere. Two of the Shorthorns remained in their natural coats; the other two were clipped immediately prior to each test. The heat tolerance of the clipped Shorthorns was clearly superior to that of the unclipped ones from June to October, inclusive. There was no difference between the groups from November to February, and in March, the clipped animals were slightly superior. The unclipped Shorthorns have shown an obvious seasonal pattern of heat tolerance. The clipped Shorthorns and the Zebu, on the other hand, reacted relatively uniformly throughout, the Zebu generally showing least rise in rectal temperature. Thus a clipped coat and a sleek, natural one conferred equal benefit in resisting hyperthermia under the conditions of the experiment.

(ii) *Seasonal Change in the Tolerance of Cattle to Direct Heating Radiation.*—The clipped and unclipped Shorthorns mentioned in (i), while undergoing the monthly heat tolerance tests, were also subjected to heating radiation from a panel of infra-red lamps. The clipped animals appeared to withstand the radiation neither better nor worse than the unclipped ones.

(*g*) *Adaptation to a Tropical Environment* (Rockhampton Laboratory). (i) *Body Temperatures and Respiration Rate.*—Several series of observations on groups of over 200 animals of the various breeds have been made. Breed differences are large. Among animals of British breed, heritability estimates are moderate, correlations with coat characters are high, and correlations with growth rate are highly significant, being highest for skin temperatures.

(ii) *Coat Characters.*—No further methods of analysis of coat characterization have been tried. The criteria adopted at this stage are coat score, weight of hair per unit area, felting, and colour. Heritability estimates for all of these are high. Correlations with body temperatures and with growth rate are high for coat score and felting.

(iii) *Sweating Rates.*—The desiccating capsule method has been applied on a large scale to give comparative data on sweating rates. Appreciably higher rates for Brahman and Afrikander cross have been observed when thermal stress is really high. There are consistent differences between animals of British breed. Suggestive relationships of these differences to coat characters and temperature regulation are being investigated further. The capsule method gave highly repeatable results, but attempts are being made to improve it.

(iv) *Sweat Gland Studies.*—Determinations of sweat gland densities and sizes are proceeding to provide for study of their variation in relation to breed, age, inheritance, body weight, growth rate, temperature regulation, sweating rate, and coat type.

(v) *Blood Studies.*—Data on blood samples taken monthly from 44 calves of Hereford, Afrikander x Hereford, and Brahman x Hereford breeding from about six and fifteen months of age have been analysed. High repeatability for individual animals has been shown for all constituents, large breed differences for most, and fairly high heritability for several. Confirmation of possible relationships with growth rate awaits data on larger numbers of animals. Constituents determined include haematocrit, haemoglobin, phosphate, alkaline phosphatase, creatinine, cholesterol, glutathione, and protein.

(*h*) *Supplementary Feeding of Beef Cattle Grazed on Sown Pastures* (Regional Pastoral Laboratory, Armidale).—In Hereford weaners grazed on a good phalaris-clover pasture, a legume-hay supplement of 5-6 lb. per head per day did not increase liveweight gains over a twelve-week period in winter and early spring. The hay supplement was given either daily or weekly. Compared to control animals, the rate of gain in liveweight was less in the treated groups in the first three weeks but was similar thereafter. At the conclusion of the experiment, the mean liveweights of the supplemented groups were still below that of the control. No significant differences in liveweight gains were observed between the groups which received the hay supplement daily and weekly. Over a six-week period in late spring, supplements of oaten grain (2.67 lb. per head per day), or peanut oil (11 fluid oz. per head per day), given on the drinking water did not increase the rate of liveweight gain in Hereford weaners grazed on a good phalaris-clover pasture.

(*i*) *Drought Feeding of Cattle.*—An investigation has commenced on the value of high roughage and of all-grain diets for cattle fed at drought feeding levels.

(*j*) *The Structure and Development of Hair Follicles and Associated Glands in Cattle* (Sheep Biology Laboratory).—Skin samples for 28 European cattle foetuses, ranging in age from 30 to 260 days, have been collected for a detailed histological study of the development of the hair follicles and associated glands. Sixteen of these foetuses have been preserved entire for later studies. On the mid-lateral region of the trunk, the first hair follicles appear at about 80 days and develop very slowly, taking more than 100 days to reach the stage when the first hairs emerge. At 260 days (about three weeks before birth), many of the follicles have completed their first cycle.

8. CATTLE BREEDING INVESTIGATIONS.

(Division of Animal Health and Production.)

(*a*) *Investigations at the National Cattle Breeding Station, "Belmont", Queensland.*—The 1956 calving completed the third mating in the two main breeding trials.

(i) *Crossbreeding Project: Rates of Growth.*—Body weights are now available from the progeny of six crosses born in 1954, 1955, and 1956. With minor variations, the relative positions of these crosses have remained the same throughout, the Afrikander or Zebu crossed with Hereford or Shorthorn giving progeny which grow faster and to heavier weights than the Hereford/Shorthorn or Shorthorn/Hereford crossbreds.

(ii) *Northern-bred and Southern-bred Herefords.*—The southern-bred cattle appear to have adapted themselves to the northern environment; their progeny born in 1955 and 1956 are comparable with those of the northern-bred group, whereas among progeny born in 1954, there is still a considerable difference in favour of the northern-bred group.

(iii) *Artificial Insemination.*—As some failures were experienced with deep frozen semen, collected from the bulls at "Belmont" by electrical stimulation, the young bulls are now being trained to permit semen collection by artificial vagina. Some artificial inseminations will be necessary owing to the increasing number of mating groups that will be required as the breeding programme progresses to selection in the F_2 generation.

(iv) *Dentition Studies.*—Preliminary observations on groups of 10 animals in the Hereford and Shorthorn breeds, and the Zebu/Hereford cross have shown appreciable differences in size and shape of the temporary incisors and in their total "span". The process of replacement of the temporary incisors also appears to differ. In the Zebu x Hereford, the temporary incisors remained intact and in wear until they were pushed out by the permanent incisors. The age at which eruption of the first permanent incisors occurred ranged from 87 to 109 weeks, but, except for a few individuals, the range was only from 102 to 107 weeks. Further observations on dentition will now be made in greater detail.

9. SWEAT GLANDS IN CATTLE.

(Animal Genetics Section.)

Work on skin in cattle and its role in adaptation to hot climates continues in the Animal Genetics Section. Cattle of European origin selected for heat tolerance appear to increase sweat gland volume by growing convoluted glands, unlike the Zebu which has large sac-like glands.

IX. ENTOMOLOGY.

1. GENERAL.

Throughout the agricultural, pastoral, and horticultural industries, Australia in common with most parts of the world suffers enormous losses from the depredations of insects. As seed, as growing crop, or as harvested food the products of the soil are continually subject to damage by many thousands of species of insects. Before a campaign against any insect can be launched with reasonable hope of success, the life history and habits of the particular species must be thoroughly investigated and understood. The Organization's investigations involving the biology and control of insect pests, the biological control of weeds, and other aspects of entomology are mainly carried out by the Division of Entomology, with headquarters in Canberra. Collaborative work is, however, undertaken by the Division on special problems in conjunction with other laboratories. Research on insects affecting animals is done partly in cooperation with the Division of Animal Health and Production and is reported in Chapters VII. and VIII. The Division cooperates with the Division of Forest Products in the study of pests of timber (*see* Section 13 of this Chapter, and Chapter XIV., Section 6 (*h*)).

Division of Entomology.—Insect ecology and insect physiology have continued to be the two principal themes of the research of the Division, but there has been a developing emphasis on cattle tick research and on the biological control of both weeds and the Queensland fruit fly.

The Division is initiating a programme of research on the biological control of Noogoora burr, and an officer has been appointed from overseas who will commence work towards the end of 1957.

An officer has also been appointed to work on the biology and ecology of fruit flies in cooperation with the Zoology Department of the University of Sydney. Plans for the extension of this work include the importation of large numbers of adult parasites from Hawaii.

The Cattle Tick Research Review Committee, appointed in 1956, has now considered the cattle tick research programmes of the Division of Entomology, the Division of Animal Health and Production, the universities, and the State Departments of Agriculture. The Committee made recommendations supporting the work planned in the Division of Entomology, and it is hoped that extra facilities will be made available in the near future at Yeerongpilly and Amberley in Queensland. More detailed knowledge of survival is required if previous work on pasture spelling is to be intelligently applied throughout Queensland, and a new appointment is proposed for the study of the survival of non-parasitic stages of the cattle tick in northern pastures.

As a logical extension of the Division's studies on the population dynamics and ecology of various insects, an officer was appointed during the year to work on orchard pest control. Before taking up duty in Australia this officer is spending 6 months in Nova Scotia as the guest of the Canadian Government, to study recent developments in the control of orchard pests involving the use of highly specialized insecticides.

The Chief of the Division was invited by the Long Island Biological Association to take part in a symposium on "Animal Ecology and Demography" at Cold Springs Harbour in June.

The Division has cooperated with the Queensland Department of Lands on Noogoora burr and lantana; also the New South Wales Forestry Commission on termite and borer work; and the New South Wales Forestry Commission in experimental aerial spraying of portion of a forest infested by phasmatids. A number of other cooperative projects with Government departments and universities are incomplete and are continuing.

The Division has continued to test plastics and other termite-susceptible materials in laboratory colonies of termites. These tests, available nowhere else in the world, have permitted a number of industrial firms to market termite-proof products.

The new conditioned rooms in the basement of the Centre Block in Canberra and the new air-conditioned brick insectary are now partly in use, although reliable control has not yet been attained.

2. INSECT PHYSIOLOGY AND TOXICOLOGY.

(Division of Entomology.)

(*a*) *Digestion of Wool by Insects.*—A comprehensive review of this subject, together with a survey of the most effective mothproofing methods, has been prepared for publication.

A number of tests has been carried out, both in Australia and overseas, with insects reputed to be able to digest wool. As a result, it is now possible to define with some accuracy those species which possess this capacity and to indicate others which cannot digest keratin, although they may occasionally chew holes in fabrics adjacent to their normal foodstuffs.

Studies on the mechanism of digestion of keratin by insects have been continued. The possibility is being examined that enzymes are concerned in a reductase system which renders keratin more susceptible to proteolysis than usual. However, no activity has so far been demonstrated either in cell extracts or in particulate fractions.

A purified clothes moth proteinase preparation is required for comparison with proteinases from other sources. Although considerable progress to this end has been achieved, somewhat disappointing results have been obtained from methods such as the use of columns of ion-exchange resin or of calcium phosphate. Paper electrophoresis studies on the enzyme preparations show promise for both analytical and preparative techniques. Knowledge gained in the clothes moth experiments is being applied to the preparation of purified carpet beetle proteinase. An examination of the effect of purified proteinase on natural and modified wools has now begun.

(*b*) *Insect Muscle Biochemistry.*—The collaborative investigation on the action of dinitrophenol on myosin has been extended. It was found that dinitrophenol stimulated the ATPase activity of myosin in experiments at 25° C., but inhibited at 0° C. Moreover, the extent of the activation at 25° C. was dependent on the substrate concentration. At very low substrate concentrations there was inhibition, rather than stimulation. These effects on myosin could be duplicated by –SH reagents, such as *p*-chloromercuribenzoate or Zn^{++}, whereas the –SH reagents, used in conjunction with a maximally stimulating concentration of dinitrophenol, caused marked inhibition. These facts have important implications in the light of recent work on the size of the myosin molecule, and a hypothesis has been put forward to explain the action of dinitrophenol in terms of its effect on a temperature-dependent polymerization of myosin.

Work is continuing also on the preparation of a textbook on the biochemistry of insects.

(*c*) *Cuticular Chitin and Protein.*—A chitin has been isolated from crab cuticles by the use of ethylenediaminetetraacetic acid over the pH range 3 to 9; this avoids the hitherto prevalent use of strong acids and alkalis which may effect structural changes in the chitin. The isolated chitin contained about 5 per cent. of a protein which was not soluble in water, aqueous phenol, or dimethylformamide. Although the chitin could be dispersed in anhydrous formic acid or in aqueous lithium thiocyanate, no protein-free fraction could be obtained. Repeated extraction with hot aqueous alkali substantially reduced, but did not eliminate, the protein. It is concluded that the protein is chemically bound to the chitin. The experimental evidence also suggests that chitin may be polydisperse. Chitin always occurs in association with protein, and there has been speculation in the literature as to whether arthropod cuticle contains a glycoprotein resulting from the chemical combination of chitin and protein. In the present instance this appears to be so. Previous work has shown that there is a weak bonding (adsorption) between chitin and the water-soluble cuticular proteins, and it is now concluded that the remaining proteins are chemically bound to the chitin.

(*d*) *Sensory Physiology.*—Work dealing with the oviposition responses of the sheep blowfly is reported in Chapter VII., Section 20.

3. INSECTS AND VIRUSES.

(Division of Entomology.)

(*a*) *Insect Tissue Culture.*—Further studies have been made of additional tissues and of the chemical requirements for their growth in culture. Although the amount of growth was not increased significantly, a marked beneficial effect on the cells was obtained by adding to the medium all the vitamins of the B complex. No effect was obtained by adding cholesterol or nucleic acid.

When either a hormone extract obtained from the ring glands of *Lucilia cuprina* and the prothoracic glands of *Periplaneta americana* or an extract of the ovaries of the silkworm was added to the medium, the increase in growth and survival of the tissues was very marked. Mitotic divisions were numerous for 16 days and the cultures survived for about 3 weeks.

It has been shown conclusively that the only cells which grow in culture are those of the lining of the ovarioles. By increasing the cell concentration in the medium the survival of the tissues was increased from 16 to 21 days.

(*b*) *Leafhopper-borne Virus Diseases of Plants.*—The maize wallaby ear disease was studied further and an attempt made to determine whether this disease is of virus origin, or the result of insect toxin. As the result of a field survey the disease is now known to occur in the coastal areas of northern New South Wales. It was identified during early November at Tygalgah, Fernmount, and as far south as Wauchope. Previous records had indicated that it was a disease of late planted crops. Glass-house experiments showed a reduction of approximately 14 per cent. in dry weight of infected grasses.

A field survey through central western New South Wales, south-eastern Queensland, and coastal areas north of Sydney showed that legume little leaf and rugose leaf curl virus diseases are restricting the value of legumes in improved pastures in south-eastern Queensland. Rugose leaf curl is killing red clover and lucerne and producing marked stunting of white clover during spring and autumn. Tests carried out for the Queensland Department of Agriculture and Stock demonstrated both of these diseases in infected peanut material collected at Kingaroy.

(*c*) *Aphid-borne Diseases of Subterranean Clover.*—Further studies with this disease have shown that it is caused by a persistent type virus and that the host range includes some subtropical legumes. The method of survival from season to season is being investigated.

4. FIELD POPULATION STUDIES.

(Division of Entomology.)

Again the year's work has consisted mainly of studies on outbreaks of the psyllid *Cardiaspina* which is causing increasing damage and destruction to *Eucalyptus blakelyi* in the Canberra district. At higher densities, the numbers of *Cardiaspina* appear to be determined largely by a complex interaction of population density and food supply. This involves the amount of space favourable for oviposition, which is limited by damage to foliage caused by the feeding of the insect.

For those parts of the Canberra district in which *Cardiaspina* has persisted at very low levels, evidence suggests that its population density is controlled by either one or two species of encyrtid parasite. Each of these parasites appears to react to increase in psyllid numbers by causing a related marked increase in mortality, at least during the time when the hunting periods of the adult parasites are well synchronized with the presence of psyllids vulnerable to attack.

Field surveys in New South Wales and Victoria indicate that persistent outbreaks of *Cardiaspina* are confined to the colder parts of its range. A preliminary analysis of weather conditions and associated life-cycle data suggests that a continuance of temperatures lower than average in such areas may be the ultimate cause of the outbreaks—by inducing frequent breakdowns in host-parasite synchronization.

5. Locusts and Grasshoppers.

(Division of Entomology.)

(*a*) *The Australian Plague Locust.*—Testing of the effect of the shrub-planting treatment in selected outbreak centres of the Australian plague locust was suspended during 1956-57 pending an analysis of the results already obtained. As previously reported, shifts in the distribution of the non-swarming population within the outbreak area have greatly complicated this work, and it may have to be concluded that an adequate test is impossible because of this factor.

Further work has been carried out in connexion with the projected Commonwealth-State trial of the control strategy of outbreak suppression. This is intended to test the technical possibility of crushing an outbreak in its early stages and to indicate the cost of the strategy in relation to that of control campaigns as conducted in the past in Australia. The trial is to be run by a committee of management consisting of representatives of C.S.I.R.O. and the New South Wales and Victorian Departments of Agriculture. A technique has been worked out for assessing periodically the locust density over the Bogan-Macquarie outbreak area, where the trial will be carried out. Maps showing the density at selected centres are prepared for each generation of locusts. In this way the committee of management is enabled to follow the fluctuations in density and will receive ample warning of the development of densities likely to lead to swarm formation. Three such maps have so far been prepared, covering assessments made in November, 1956, and January and April, 1957. They show a fairly uniform low density, which could not be expected to give rise to swarming in the next generation.

Other preparations for the trial campaign include the compiling of maps and indexes giving particulars of all properties in the outbreak area. A survey of soil boundaries is being carried out as an aid to the recognition of outbreak centres. The whole outbreak area has been divided into twenty "operational areas" to each of which one spraying unit will be allotted.

During February a reconnaissance was made of certain minor outbreak areas in western New South Wales at the request of the Victorian Department of Agriculture. The locust density was found to be well below the danger level.

(*b*) *Solitary Grasshoppers.*—Surveys of *Phaulacridium vittatum* and *Brachyexarna lobipennis* during this summer showed that, in native pastures dominated by perennial grasses, the former occurred in insignificant numbers, whereas the latter was numerically the most abundant species of grasshopper. *Phaulacridium* occurred at high density in various types of disclimax communities, e.g. overgrazed pasture, formerly cultivated land now abandoned, &c. and in much smaller numbers in improved pastures of high quality. In these latter types of pasture *P vittatum* greatly outnumbers *B. lobipennis.*

The survival of large numbers of adult *P. vittatum* depends on the presence of a high proportion of summer-growing species of plants which are capable of a rapid and prolonged vegetative response to light falls of rain. It shows a preference for predominantly short pastures with scattered, taller plants that provide roosts when surface temperatures rise or fall beyond certain critical thresholds, and avoids dense, tall vegetation or areas dominated by tussock grasses above a few inches in height. Its requirements for both shelter and food are therefore met in overgrazed pastures.

Intensive study of a dense population in a favourable site at Gungahlin, Australian Capital Territory, showed clearly that adult *P. vittatum* experienced a shortage of food which induced competition and mortality in January, 1957. Birds, other predators, and parasites appeared to be incapable of governing the density of this species.

Studies in areas of improved pasture showed that the dense, complete cover of subterranean clover delays the time of emergence of both *Phaulacridium* and *Brachyexarna* by one or two months when compared with the corresponding times of their emergence in native pastures. Most of the nymphs of each species emerged when the clover had dried out and collapsed. The numbers of both species in plots on improved pasture were closely related to the density of Scotch thistle. Cutting of the thistles caused a complete disappearance of the grasshoppers from such sites. These data help to explain the patchy distribution and relatively low numbers of both species in areas of improved pasture with a complete cover of subterranean clover.

Observations have been made on other species of grasshopper in the Southern Tablelands district.

6. Pasture Cockchafers.

(Division of Entomology.)

(*a*) *The Black Beetle.*—The extreme scarcity of this species continued during the present year. Numbers of the insect fell to such low levels that field studies were discontinued. Although the past summer was probably favourable to its increase, only one report of the insect was received during the autumn, the period when crop damage is most severe.

(*b*) *The Pasture Scarab.*—Studies on this pest of improved pastures (*Aphodius howitti*) are largely concluded, but certain long-term field studies concerned with its natural control and distribution are being continued. This insect has been present only at very low densities during the past few seasons.

7. Pasture Caterpillars and Taxonomy of Lepidoptera.

(Division of Entomology.)

Field observations have continued on the seasonal abundance, pest importance, and ecology of a series of noctuid cutworms and armyworms with special reference to *Agrotis infusa* and its allies. An extremely high adult population of *A. infusa* aestivated at Mt. Gingera in the Brindabella Range, Australian Capital Territory, in the summer of 1955-56, and reports early in the winter of 1956 indicated that heavy damage could be expected to pastures and field crops, especially in northern New South Wales and southern Queensland. However, a high natural larval mortality resulted in only slight damage and a greatly depleted emergence of adults during spring in 1956. There was some evidence that adult diapause in these moths was of much shorter duration than in previous years and the causes of this are being studied. The excessively dry summer may have contributed. The resulting early exodus of most moths from the aestivation sites, together with a very dry autumn, suggests that little or no economic damage should occur in the winter of 1957. Laboratory experiments on the biology of *A. infusa* are continuing and will be greatly assisted by new constant-temperature facilities.

Taxonomy.—A comprehensive reclassification of the Australian genera and species of Tortricidae is now nearing completion, and a revision of the Australian cutworms of the genus *Agrotis* (Noctuidae) has been completed and is now ready for publication.

A revision of the pink bollworms of cotton and related species (Gelechiidae) undertaken at the request of the quarantine authorities is nearing completion. A claim, made many years ago, that the pink bollworm (*Pectinophora gossypiella*) does not occur in Queensland has been confirmed. Complete justification is thus provided for the maintenance of quarantine measures prohibiting the passage of untreated seed cotton to that State.

8. RED-LEGGED EARTH MITE AND LUCERNE FLEA.

(Division of Entomology.)

(*a*) *Insecticidal Control.*—Following recommendations issued in 1956, between 300,000 and 400,000 acres of pastures and crop were sprayed in Western Australia with a mixture of malathion and DDT. As a result of this field experience, the malathion dosage rate now recommended is 1 oz. active ingredient per acre.

(*b*) *Population Studies.*—Samples of lucerne flea populations were collected in 1956 from the observation areas at Moora and Waroona. Twice-weekly collections provided information on changes in age composition, rates of development, and mortality rates of local populations in improved pastures. Significant negative correlations between autumn and spring densities were obtained in each area. The change in distribution pattern was due largely to heavy mortality, particularly of the early instars, in the densely populated areas. There was also some evidence of a decrease in fertility in these areas. At Waroona, where a dense population developed in the third generation in late August, very heavy mortality in the early instars reduced the population by 75 per cent. in three weeks, despite favourable climatic conditions and a good stand of pasture. Practically no fleas lived beyond the second instar. The cause of this high mortality was not discovered.

From equal initial densities, higher populations developed in areas in which the predatory bdellid mite was virtually eliminated by DDT treatment and in areas in which cape-weed was more plentiful.

(*c*) *Studies on Diapause.*—Two experiments were conducted on the influence of temperature and humidity on diapause development in the aestivating eggs of the red-legged earth mite. Hatches were obtained after exposure to temperatures ranging from 30 to 70° C. and humidities from 80 to 21 per cent. R.H. The most successful condition for breaking diapause was exposure to 50° C. and 50 per cent. R.H. for 32 days.

Collections of egg-bearing mites at weekly intervals in different areas revealed a close correlation between temperature and the date of development of diapause eggs. In the warmer areas these eggs appeared up to four weeks earlier in the spring.

9. BIOLOGY AND CONTROL OF THE CATTLE TICK.

(Division of Entomology.)

This work is reported in Chapter VIII., Section 5.

10. SHEEP BLOWFLY.

(Division of Entomology.)

This work is reported in Chapter VII., Section 20.

11. INSECT PESTS OF STORED PRODUCTS.

(Division of Entomology.)

Investigations into the effects of air-tight storage on insect pests of stored grain have continued. A study of the large strain of the rice weevil *Calandra oryzae* has been completed, and work has begun on four other species of pests including the lesser grain borer *Rhizopertha dominica*.

Experimental work on air-tight storage carried out in a partly sealed silo operated by the Grain Elevators' Board of New South Wales has given very variable results, but it is clear that a great deal more knowledge is needed about the diffusion of oxygen and carbon dioxide through bulk infested grain.

Cooperation with the Department of Primary Industry has continued with further investigations into the infestation problems of flour mills. It has been shown that, in most instances, the insects occurring on the finished flour have originated from the mill or its ancillary premises. In the case of export flour it is believed that further infestation has been acquired from other commodities stowed close to flour in ships' holds, and arrangements have been made to prevent this trouble in the future.

An examination of infestation problems of the Dried Fruits Industry has also been carried out at the request of the Department of Primary Industry. Advice has been given on the fumigation of fruit with methyl bromide and on the protection of packed fruit by pyrethrum film spraying, both new techniques to the industry.

12. BIOLOGICAL CONTROL.

(Division of Entomology.)

(*a*) *Weed Problems.* (i) *St. John's Wort.*—Further liberations of chrysomelid beetles, mainly *Chrysomela quadringemina,* have been made at Gingellic and near Tumut in New South Wales. At Myrtleford, in Victoria, the gall-fly *Zeuxidiplosis giardi* has survived under field conditions since November 1954, and appears to be well established. Colonies have been liberated in other parts of Victoria and in New South Wales.

(ii) *Ragwort.*—During the flowering season of ragwort (January-February) further liberations of *Tyria jacobaeae* were made in Gippsland, Victoria. In addition, adult progeny from the previous liberations were recovered, which gave rise to the first complete Australian generation. Efforts are being made to determine the factors governing the population of *T. jacobaeae* under these Victorian conditions. Mass breeding of *Tyria* for further liberation is planned.

(iii) *Lantana.*—Following food tests carried out in Hawaii and Queensland by the Department of Public Lands of Queensland, in consultation with the Organization, three species which attack lantana have been introduced into quarantine in Australia, and permission to liberate *Catabena esula* has been given by the Commonwealth Department of Health.

(iv) *Crofton Weed.*—Favourable reports have been received from Queensland of the effect of *Procecidochares utilis,* which was introduced several years ago by the Queensland Department of Public Lands in consultation with the Organization. The reports indicate that Crofton weed is now generally stunted in growth, and the area infested is apparently no longer extending.

(*b*) *Insect Problems.* (i) *Pests of Crucifers.*—Field studies have provided additional information on the possibility of controlling *Pieris rapae* and *Plutella maculipennis* with reduced insecticidal schedules. In summer plantings, cabbages of satisfactory commercial quality were obtained with a single application of lead arsenate. Under these conditions, no insecticides were required for cabbage aphid, which was well controlled by natural enemies.

(ii) *Green Vegetable Bug.*—An Italian strain of *Microphanurus basalis,* introduced during the year, has been cultured on a large scale and made available to all the mainland States of Australia. The distribution of the West Indian strain has ceased. Laboratory studies on certain aspects of reproduction in *Ooencyrtus* are continuing.

(iii) *Queensland Fruit Fly.*—Two braconid parasites, *Opius longicaudatus* and *O. oophilus,* which are established in Hawaii as parasites of the Oriental fruit fly, have been shown to parasitize Queensland fruit fly in the laboratory, and both have been released in the field, the latter in small numbers, during the year. They were liberated at Coff's Harbour and at Sydney, but did not become established, although a few wasps were reared from fruit samples taken at relatively short periods after liberation.

The efficiency of culturing the two opiine parasites has been greatly increased by the use of a larval medium, based on dried carrot, which was developed in Hawaii for culturing the Oriental fruit fly. This has improved the production of *O. longicaudatus*, and has made it possible to culture moderate numbers of *O. oophilus*.

(iv) *Wax Scales.*—The distribution of *Ceroplastes rubens* and *C. destructor*, their predators, and their parasites has been surveyed. This will serve as a basis for determining what insects attacking these scales in other countries should be introduced here.

(v) *Aphid Parasite and Predator Studies.*—The survey of the aphid fauna of Australia and of their parasites and predators has been continued. Many species not previously recorded have been found, and two new species of Aphididae have been described which are thought to be endemic.

13. TERMITES AND OTHER WOOD-DESTROYING INSECTS.

(Division of Entomology.)

(*a*) *Termite Investigation.*—The first laboratory colonies of *Coptotermes frenchi* were installed during the year and showed that this species is comparable in food preferences and voraciousness with its important economic congener, *C. acinaciformis.*

Tests of the third group of Australian commercial timbers against *Nasutitermes exitiosus* and *Coptotermes lacteus* are now almost complete and these confirm the order of decreasing resistance given in the previous report: *Eucalyptus rostrata, E. propinqua, E. punctata, E. saligna, E. eugenioides,* and *E. sieberiana.* An investigation of the durability of teak (*Tectona grandis*) is being made in cooperation with the Division of Forest Products.

The investigation of the factors responsible for the natural resistance of black bean, *Castanospermum australe,* is continuing in cooperation with the School of Applied Chemistry, New South Wales University of Technology. Extracts made with certain solvents have been shown to have an anti-termitic effect.

In tests of the termite resistance of plastics, (i) thin films of polyethylene, polyvinylidene chloride, and polyvinyl chloride have been shown to offer no serious barrier to penetration by termites, and (ii) cable sheathings of polyvinyl chloride containing fractional percentages of aldrin or dieldrin were immune to attack, although the permanence of such treatments is not yet known.

Field tests of surface treatments with creosote, sodium arsenite, chlordane, dieldrin, and pentachlorphenol have shown that all treatments give at least two years' protection against *N. exitiosus.* Similar tests have now been installed with *C. lacteus.* The final examinaion of the condition of samples in the International Termite Exposure Test was made after 27 years' service, and a report was forwarded to the Forest Products Laboratory, Madison, United States of America.

Observations on soil treatments for termite control have been continued: against *N. exitiosus,* 5 per cent. DDT broke down after seven years; against *C. lacteus,* 5 per cent. pentachlorphenol and 5 per cent. DDT failed after six years. In comparable tests against these two species, and in the Riverina against a termite complex of *Coptotermes frenchi, Heterotermes ferox,* and *Microcerotermes* sp., a number of other insecticides remain effective after periods of time ranging from two to four years.

(*b*) *Termites in Forest Trees.*—Investigations in hardwood forests near Canberra have shown that the presence of a large colony of *Coptotermes frenchi* results in increased temperature within the infested tree. The maximum increase occurs in the " nursery " region.

During the colder months of the year the difference in temperature within a sound tree and an infested tree may be as great as 40° F.

(*c*) Lyctus *Investigations.*—Observations have been continued on the relative efficiency and persistence of various surface treatments for the prevention of *Lyctus* attack. After one year's indoor weathering chlordane, lindane, aldrin, and dieldrin were still completely effective, but some pentachlorphenol treatments failed to prevent attack after six months' indoor weathering.

14. ANT INVESTIGATIONS.

(Division of Entomology.)

(*a*) *Meat Ants.*—Examinations of treated nests of the meat ant have shown that chlordane and dieldrin are more persistent than DDT for preventing ants from neighbouring colonies occupying treated nest sites.

Twenty-seven months after treatment only one of 24 nests was occupied following treatment with either dusts or sprays containing chlordane or dieldrin.

(*b*) *Argentine Ants.*—The eradication campaign in Sydney, in co-operation with the New South Wales Department of Agriculture and local government bodies, was continued during the year.

Twenty-eight new infestations were found, bringing the total to 153 separate infestations in the Sydney area. Several of the new infestations were found in outer suburbs at Riverstone, Galston Gorge, Castle Hill, and Cronulla. Thirty-seven areas totalling 480 acres were sprayed from July, 1956, to May, 1957.

An examination of areas sprayed with chlordane or dieldrin from 1952 to 1956 showed very few persistent infestations. Eighty-three of the 95 areas examined were apparently free from Argentine ants.

15. INSECTICIDE INVESTIGATIONS.

(Division of Entomology.)

The nature of insect resistance to insecticides has been further studied in several strains of house fly. An important advance was the demonstration that DDT-dehydrochlorinase, an enzyme which detoxifies DDT, is present in two strains of flies which had previously been found to be specifically resistant to DDT. Both strains had been derived from a non-resistant laboratory colony, one by repeated selection with DDT, the other by breeding only from late emerging flies without exposure to insecticide. Analyses of dosage-mortality data for successive generations of these selected strains has indicated that approximately the same level of DDT resistance was attained by the two methods of selection. Enzyme activity in the two strains was also approximately the same. It is clear that some flies possess the DDT-dehydrochlorinating enzyme, although neither they nor their ancestors have ever been in contact with insecticides.

Preliminary work on the lipids present in house flies indicates that lipid content varies with age in the same way as tolerance to the lipid-soluble insecticides. Differences in lipid content between flies of various strains have been found to be insufficient to account for the relative DDT tolerance of the strains.

16. TAXONOMY.

(Division of Entomology.)

A request that the Division should investigate the biological control of rice stem borers in northern Australia has brought to light the fact that practically nothing is known either of the native insects of this group or of their parasites. Before anything can be done about biological control the taxonomy of the pests and their parasites must be investigated.

This one example illustrates a not uncommon occurrence, and provides further justification for taxonomic studies which are in progress throughout the Division in association with ecological work. The most intensive studies are concerned with certain of the Diptera, and the Chalcidoidea and other parasitic and predatory Hymenoptera. As in the past, overseas taxonomists are also being encouraged to work on Australian groups.

17. MISCELLANEOUS.

(Division of Entomology.)

(*a*) *Stick Insects*.—Kentromorphic phase differences, similar to those in locusts, have been shown to occur in the three species of stick insects (Phasmatidae) that damage eucalypt forests in eastern Australia. The phases of these species are described in a forthcoming publication and some new suggestions made regarding the biological significance of the phenomenon. Recognition of the phases is likely to be of value in forestry practice, since it enables the density level of a given infestation to be estimated from the appearance of a small sample of specimens collected by untrained personnel.

(*b*) *Defoliation of Eucalypts*.—Because of the enormous variation in the attractiveness of eucalypts to phytophagous insects, studies are being made of the host specificities of most of the more important defoliating insects. Preliminary surveys suggest that the attractive factors present in the host trees may be transmitted in varying degrees to their hybrid progeny, and hybrids have been produced that are relatively free from insect damage. The use of hybrids in plantings may offer a partial solution to the defoliation problem.

(*c*) *Bush Fly*.—This notorious nuisance fly becomes a severe pest of stock in some low rainfall areas of Australia, but its breeding medium in those areas is unknown. In the Canberra area it has been found that the numbers breeding in cow dung adequately account for the local population. All the larval instars have been isolated, and found to be distinguishable from those of *Musca domestica*. This should facilitate studies of breeding sites in the arid areas.

X.—WILDLIFE.

1. GENERAL.

In every country in the world mammals and birds, both native and introduced, affect primary production and other human activities in a variety of ways. In Australia, what may conveniently be termed wildlife problems range from that of the rabbit, the country's most serious pest, to the mutton bird, on which a small but valuable local industry depends. Kangaroos, opossums, and wild ducks and geese of various species may be pests at various times and in parts of their range, while calling for conservation elsewhere because of their economic value or their importance as game. To deal with wildlife problems that called urgently for solution or merited scientific study for other reasons, the Organization established its Wildlife Survey Section in 1949.

In many of its investigations the Section depends materially on collaboration with State departments, with universities (particularly the Australian National University), and with other branches of the Organization, while most of its field work would be impossible without the assistance of individual landholders.

Wildlife Survey Section.—This year saw the issue of the first two numbers of a new periodical, *C.S.I.R.O. Wildlife Research*, which has been begun to provide a vehicle for the publication of the results of the Section's investigations.

The close relation between the Section and the Antarctic Division of the Department of External Affairs has continued; and it has again been possible to second a member of the Section's staff to the Australian National Antarctic Research Expedition to carry out biological observations on Macquarie Island.

2. RABBIT INVESTIGATIONS.

(Wildlife Survey Section.)

(*a*) *Myxomatosis*.—The work on rabbit myxomatosis has continued under two main heads, the intensive study of disease activity, rabbit populations, and insect vector production in a number of representative areas, and co-operation with the Microbiology Department of the Australian National University in its studies of virus variation, immunity, and resistance. In addition, surveys have been carried out to get an overall measure, within a region, of myxomatosis performance and the degree of rabbit recovery together with an indication of other factors affecting rabbit population levels. There is accumulating evidence that climatic factors unfavourable to breeding have contributed to the continuing general low level of infestations.

The areas in which the epidemiology of myxomatosis has been studied intensively are located in the following regions:—(i) New England, (ii) the south coastal ranges of New South Wales, (iii) the Victorian Mallee, and (iv) the Victorian Wimmera. The picture in the Victorian study areas was found to be comparable with the one that had been well worked out in the Riverina, hinging on two important, and one not-so-important, mosquito vectors (*Anopheles annulipes, Culex annulirostris,* and *C. pipiens australicus* respectively), with the usually annual disease outbreak having an intensity and timing that is predictable on seasonal rainfall.

Vector conditions in the south coastal ranges were found to be complex, and the possibility that a meteorological factor, affecting mosquito activity generally, was responsible for the tendency to late summer-autumn outbreaks was investigated in collaboration with the Division of Meteorological Physics.

In New England, the study of vector ecology combined with an analysis of rainfall records has shown that useful myxomatosis activity can be expected in this region only after either a spectacular fall or a continued long period of rain. Good late summer-early winter outbreaks can be expected to occur one year in five or six, and spring-early summer outbreaks only about one year in twenty. (New England has experienced only one general outbreak since myxomatosis was liberated in 1950.)

Special attention has been paid in the coastal range and New England studies to the feeding behaviour of the various mosquito species, and with the co-operation of the School of Public Health and Tropical Medicine in Sydney some of the best data on record on the natural feeding of mosquitoes have been collected.

The first consignments of the European rabbit flea (*Spilopsyllus cuniculi*) have been obtained from Britain, and the adults that have emerged are being held under quarantine in Canberra. When a satisfactory technique for breeding the insects in the laboratory has developed, tests with representative native mammals and domestic animals will be carried out before a permit for liberation is sought.

In the co-operative investigations with the National University, Wildlife Section field officers have collected material required for the study of changes in virus virulence and the build-up of resistance in wild rabbit populations. In the Wimmera study area, a large-scale release of standard virus was undertaken to determine whether an outbreak of a virulent infection could be artificially induced in the presence of naturally occuring attenuated strains. The tests of recovered virus material are not yet completed.

(*b*) *Rabbit Ecology and Control*.—The development of an effective general policy of rabbit control must depend ultimately on a sound understanding of the basic biology of the animal and the factors affecting its population dynamics, e.g. natural longevity, fecundity, mortality, and the reactions of the population to seasonal changes in the environment, particularly the food supply. As no satisfactory method has been discovered of getting the required data from natural populations, it was decided to experiment with marked populations confined under near-natural conditions in enclosures. A second pilot experiment has been carried out in a two-acre plot; techniques for handling nestlings and for census taking have been improved, while data on nestling growth and mortality were collected. The first of the full-scale studies planned is now under way.

The results of a study of the relation of environmental factors to rabbit breeding in two climatically dissimilar areas in New South Wales are now being prepared for publication.

A further enclosure experiment at Woodbury, Tasmania, was designed to test whether the normal field practice of furrow poisoning could be improved. The behaviour of rabbits during free-feeding was observed at night by means of spotlights, and radioiodine tracer in the baits revealed which individuals had fed. The results indicate that there is an advantage in feeding at intervals of several days, and that carrot is preferred to apple.

Over the past five years, the Tasmanian Department of Agriculture has developed a State-wide programme of rabbit control based on sodium fluoroacetate (" 1080 ") poisoning. To assess the efficacy of the policy and techniques used over a run of years, during which it is to be expected that the " resilience " of rabbit populations will vary substantially according to the differing seasonal conditions, a long-term survey of a representative area was initiated, and was continued during the year, with the collaboration of the State department. It is as yet too early to draw positive conclusions from the data that have been collected.

3. KANGAROO INVESTIGATIONS.

(Wildlife Survey Section.)

Work on the euro or hill kangaroo, *Macropus robustus,* has continued at Woodstock Field Station, situated between Port Hedland and Marble Bar, Western Australia. In a survey of the region, only in a few circumscribed areas were euros found to be sufficiently dense to compete significantly with sheep for pasture and to retard its regeneration. The extent of the economic problem presented by the euro and improved methods of control are being investigated.

The development of satisfactory methods of live-trapping and marking euros enabled the drinking pattern of the local population to be studied. It was found that, at the height of the dry season, 60 per cent. drank only once or twice in fourteen days, with a few drinking more often and some not drinking at all within the period. From the data obtained in this study one can calculate that poisoning would have to be continued for at least a fortnight to obtain an 80 per cent. kill. Field trials, using " 1080 " and arsenic compounds in drinking water, support this conclusion, and also indicate that effective poisoning could be carried out for about £1 per 1,000 acres.

Urine and blood tests, carried out in co-operation with the University of Western Australia during the drinking study just mentioned, showed that euros could tolerate intense dehydration and suggested that they suffered a water and nutritional crisis during the " dry ". A study of the euro's physiological adaptations to arid conditions is being planned, as it will help towards a true understanding of its relation with sheep and the red or plains kangaroo (*Macropus rufus*) as ecological competitors.

A preliminary survey was undertaken in the Eastern Goldfields region, an area of low and unreliable rainfall where competition of the plains kangaroo with sheep appears to be of a much more serious nature than that between euros and sheep in the Woodstock area.

4. MARSUPIAL SURVEY, NEW SOUTH WALES.

(Wildlife Survey Section.)

The investigation of the status of the marsupials in New South Wales was concluded during the year, and it is hoped to publish the results with distribution maps shortly. Expeditions to various parts of the State resulted in many valuable records of sightings and several specimens for examination, while contacts resulting from a widely circulated questionnaire produced useful records and some very interesting specimens. Lesueur's rat-kangaroo, *Bettongia lesueur,* and the lesser brush-tailed phascogale, *Phascogale calura,* have been added to the list of marsupials occurring in New South Wales, and a specimen of the rufous rat-kangaroo, *Aepyprymus rufescens,* from the Barrington Tops region was the first recording for the State since 1929.

A subsidiary study of the reproductive behaviour and rate of growth of the yellow-footed marsupial mouse, *Antechinus flavipes,* has also been investigated. A pair of adults was successfully bred in captivity and a litter of six juveniles has been reared. Growth and weight curves of the juveniles have been obtained since birth.

5. STUDIES OF THE POSSUM.

(Wildlife Survey Section.)

In August, 1956, a study of the role of dispersal in population regulation of the brush-tailed possum, *Trichosurus vulpecula,* was commenced near Canberra, Australian Capital Territory. Through the year 104 adult animals in the selected study area were marked and 77 pouch-young recorded. From recapture figures it seems that there is either a heavy mortality of young possums or that their dispersal rate is high—neither concept has yet been proved, though there is evidence to support the latter. It is planned to continue studies of this animal in the coming year with particular attention being given to the fate of the immature young, and to the role of territory in population regulation.

6. MAGPIE GOOSE INVESTIGATIONS.

(Wildlife Survey Section.)

The study of the magpie goose, *Anseranas semipalmata,* and its relation to the rice growing in the Northern Territory has been continued, and it has been possible to determine the main movement, feeding, and breeding patterns of the species. It is strongly nomadic, and its movements are regulated by the availability of food. The breeding season is determined in its onset and duration by rainfall and flooding of the plains.

The work indicates that the most profitable approach to protecting the rice crops would be based on the manipulation of the birds' breeding habitat.

7. WILD DUCK INVESTIGATIONS.

(Wildlife Survey Section.)

Wild ducks affect man and his activities in Australia in several ways: certain species show an unwelcome interest in crops, particularly irrigated rice; they are, by a wide margin, Australia's most important game birds; and there is reason to believe that they play an important role in the epidemiology of Murray Valley encephalitis. Studies of the feeding habits, breeding biology, and population movements of the more common species of wild ducks were initiated some years ago, and were continued during the year. From the data already collected it has been possible to reassess the economic importance of wild ducks in the Murrumbidgee Irrigation Areas, a report on which has been prepared for publication.

Owing to unprecedented flooding of the Murrumbidgee River during the winter of 1956 extensive duck breeding developed, so the studies of environmental factors affecting this process were continued; and this time it was possible to include the pink-eared duck, *Malacorynchus membranaceus,* whose breeding is erratic.

During the summer, full-scale banding of five species of wild ducks was begun, and 4,000 birds were branded. Emphasis was placed on banding ducklings or juvenile birds known to have been bred on the banding site. Bands placed on birds in the Griffith area, central New South Wales, have been recovered as far afield as Perth, Western Australia, and Roma, Queensland.

8. MUTTON BIRD INVESTIGATIONS.

(Wildlife Survey Section.)

The joint investigations with the Tasmanian Fauna Board into the economic biology of the mutton bird, *Puffinus tenuirostris,* were continued with three periods of field work in the Flinders Island region, Tasmania, which is the head-quarters of the commercial operations on the bird. These comprised: November-December, for the annual census of the breeding population at Fisher I., which is maintained as a field research station; January, for the special study of the young, pre-breeding adults; and March-April, for the marking of the fledglings and an assessment of the intensity of commercial harvesting by the application of the "Lincoln Index". During the year 2,200 birds were banded including some in the Nuyt's Archipelago, off Cedune, South Australia; in all 20,321 have been banded since the investigations began. Study has continued on the period of immaturity of mutton birds, and a pathological investigation is in progress concerning the serious mortality among fledglings on Great Dog Island during the 1957 commercial season.

9. MALLEE FOWL STUDY.

(Wildlife Survey Section.)

The mallee fowl, *Leipoa ocellata,* has been studied on a part-time basis for some years in an attempt to determine details of its unique methods of incubation, and the needs for its conservation. As a result the incubation methods have been described in detail, and it has been shown that though the introduced fox removes a high proportion of the eggs laid, the mallee fowl has maintained its density in areas where foxes abound. It is considered that the fox is not the cause of the overall decline of the mallee fowl, but rather the changes induced in the environment by man.

10. OTHER BIRD INVESTIGATIONS.

(Wildlife Survey Section.)

The second year of the magpie study near Gungahlin, Australian Capital Territory, confirms that the population consists of the two distinct but interacting elements, the small social groups of fixed location and identity and the large, more mobile flocks. A study of the mortality of these birds was carried out, and a series of microorganisms of medical and veterinary importance was found to affect them.

The attempt to eradicate breeding ravens, *Corvus coronoides,* from 5 square miles by shooting and trapping proved the existence of an immediate reservoir of replacements.

Several species of the parrot and cockatoo group are becoming agricultural and forest pests in Western Australia. As a result the movements of two species, *Calyptorhynchus baudinii* and *Barnardius zonarius,* are being studied.

The bird-banding scheme has considerably increased its membership and scale of operations, and useful data on the migrations and habits of many species are accumulating. A detailed annual report is published.

11. MACQUARIE ISLAND.

(Wildlife Survey Section.)

A member of the Section is continuing the bird and mammal survey. Progress has been made in the study of breeding and age determination in the elephant seal, and in solving the difficult problem of marking penguins individually by means of flipper-bands.

XI. UNDERDEVELOPED REGIONS.

1. GENERAL.

Resulting from such factors as low rainfall, short growing season, inadequate water, poor soils, or remoteness from centres of population, there are great areas of the Australian continent and the territories which are underdeveloped or only very sparsely occupied.

In order that these may be protected from over-exploitation and that their full productive potential can be developed, it is necessary to assess and understand the many scientific problems associated with such areas.

The Organization's Division of Land Research and Regional Survey is engaged on a series of land surveys of the underdeveloped regions to study their needs and potentialities. These surveys provide a description of the land of the region, an assessment of the possibilities of land use, and an analysis of the major problems which retard more intensive development and warrant more detailed examination. These problems are of three main kinds: those of dry-land agriculture and of irrigated agriculture in the dry monsoon zone of the far north, and those of the pastoral areas of the inland lower-rainfall zones. To further examine the initial findings of the surveys, research centres have been established at Katherine, Kimberley, and Alice Springs.

In addition to the work of the Division of the Land Research and Regional Survey in the sparsely populated and semi-arid regions of the continent, much complementary work is also being carried out by other Divisions of the Organization on the development of low-producing areas in the less isolated regions.

The Division of Biochemistry and General Nutrition is investigating problems of plant and animal nutrition on the Coonalpyn Downs in South Australia (*see* Chapter VI., Section 11), the Division of Animal Health and Production is breeding cattle at "Belmont", Rockhampton, Queensland (*see* Chapter V., Section 9), the Plant and Soils Laboratory is studying the wallum country in eastern Queensland (*see* Chapter III., Section 21), and the Division of Soils is making soil surveys throughout the Commonwealth (*see* Chapter II.). Allied work is also carried out by the Division of Plant Industry on plant and pasture ecology (*see* Chapter III.).

Division of Land Research and Regional Survey.—During the year the former Section was raised to the status of a Division.

The Division's work on geomorphology has now been expanded and a senior officer appointed to develop this work.

The Chief of the Division was the Australian delegate to the Fifth Session of the International Rice Commission at Calcutta in November, and is currently Vice-Chairman of this Commission.

Two officers of the Division were delegates to the Australia-U.N.E.S.C.O. Symposium in Arid Zone Climatology held in Canberra in October. In his capacity as Arid Zone Research Liaison Officer, the Chief of the Division issued the first annual *Arid Zone Newsletter* in October, 1956, which is intended to keep all those working in this sphere informed of progress in the various fields.

During the year the Division co-operated with the Commonwealth Department of Territories in the surveys of Papua-New Guinea; the Sydney University in studies of nitrogen metabolism in northern soils; the Australian National University in the historical-geographical survey of underdeveloped regions; with the New South Wales authorities and other Divisions in a survey and assessment of the Yass Valley.

Acknowledgments are made to the Bureau of Mineral Resources which made a geologist available to the mainland survey; the Division of Soils which seconded a pedologist to the mainland survey; and the Western

Australian Department of Agriculture for the continuation of the long-standing partnership in the conduct of the Kimberley Research Station.

2. REGIONAL SURVEYS.

(Division of Land Research and Regional Survey.)

The two regional survey units of the Division have continued operations, one on the mainland of Australia and one in the Territories of Papua and New Guinea. The first unit has been in operation in northern Australia since 1946 and has completed surveys of the following areas: Katherine-Darwin (27,000 square miles), Barkly (120,000 square miles), Townsville-Bowen (6,000 square miles), Ord-Victoria (70,000 square miles), Leichhardt-Gilbert (110,000 square miles), North Kimberley (34,000 square miles), and Georgina-Poison Country (25,000 square miles). In addition the Division has made preliminary examinations of portions of the West Kimberleys suitable for irrigation development (1952) and of the Wiluna-Meekatharra area of Western Australia (1955). The New Guinea unit was established in 1953 at the request of the Department of Territories, and has completed surveys of the Buna-Kokoda area (2,500 square miles), the Wanigela-Cape Vogel area (1,600 square miles), and the Gogol-Upper Ramu area (3,200 square miles).

(*a*) *Australian Mainland Survey Unit.* (i) *Alice Springs Area.*—The Alice Springs area is currently being surveyed. It includes almost all of the pastoral country centred on Alice Springs, together with the fringe of unoccupied " deserts ". It extends roughly 200 miles in all directions from Alice Springs, the total area being 145,000 square miles.

(ii) *Darwin-Alice Springs Transect.*—The Stuart Highway from Darwin to Alice Springs and the road southward from Alice Springs to the South Australian border runs across a number of climatic zones ranging from wet monsoonal at Darwin (60 in. rainfall) to dry areas with erratic distribution at the South Australian border (<10 in. rainfall). Also it traverses almost all of the major land types that have been recognized in the Northern Territory. In order to provide the basic data for planning agronomic and ecological investigations of the varying interactions of climatic and land type, a strip survey has been made along the full length of the road. The field work is complete, and reports and maps will be compiled in the coming year.

(iii) *Historical Studies of Development in the Northern Area and Monsoonal Lands.*—This study has been undertaken to provide information on factors which have influenced the history of development in land use and the present state and trend of development in order that they may be considered in judging future land use potentialities from the Divison's regional surveys in northern Australia.

Field work has been completed and the correlation of data is now well advanced for northern and far-western parts of Queensland. In these areas three important determinants in settlement and land utilization, apart from land characteristics themselves, have been the climatic regime, geographic isolation, and the leasehold system of land tenure. In different regions these factors interact in varying manners, e.g. the 1902 drought was a potent factor in determining the pattern of present development in the far south-west but its influence in northern parts was much less marked.

(*b*) *Papua-New Guinea Survey Unit.*—The area selected for survey in 1956 was the Gogol-Upper Ramu area near Madang. In July, August, and September, more than 3,000 square miles of country were investigated in the field, following preliminary aerial photogrammetric interpretation. An interim report of the area and three maps at a scale of two miles to the inch have been prepared for presentation to the Department of Territories.

Three-fifths of the area consists of very steep hilly and mountainous country and swamps that have very low agricultural potential.

One-fifth consists of hills with deeper, more mature soils on steep slopes which have low agricultural potential. The remainder, consisting primarily of alluvial fans and flood-plains along the coast near Madang and in the Upper Ramu Valley, has moderate to moderately high potential, but the areas of better soils are generally intermixed with poorly drained or gravelly soils.

In preparation for the full-scale survey to be made in the 1957 survey season in the Mount Hagen-Goroka area, preliminary botanical investigations were made in the field in 1956 and preliminary aerial photogrammetric interpretation has been carried out in the early part of 1957.

3. AGRICULTURAL RESEARCH IN NORTHERN AUSTRALIA.

(Division of Land Research and Regional Survey.)

(*a*) *Katherine Research Station.*—The Katherine Research Station has two main functions: (1) to examine the possibility of establishing agriculture in that portion of the area mapped by the Division's survey as the Tipperary Land System; (2) to serve as a type location and centre for the study of dry-land agriculture in the monsoonal zone of northern Australia. The research programme has now reached the stage where the most likely components of arable agriculture are becoming evident, and studies are being directed towards problems of long-term land use apart from studies of individual species. The results of the ten years' progress are being presented in a Divisional report.

(i) *Crops.*—Seasonal conditions favoured crop growing this year, but nevertheless yields proved to be very dependent on current land treatments both for this and previous years. Peanut and sorghum have proved themselves to be well-adapted crops for the Katherine area, but cotton is no longer considered satisfactory.

(ii) *Land Preparation.*—Deep ploughing in the dry season has again proved superior to shallow dry ploughing or deep ploughing after the rains have begun, in producing higher yields of sorghum and peanuts.

(iii) *Establishment.*—Comparison of methods of cotton establishment have favoured breaking down the ploughed surface with harrows, followed by consolidation by rolling. Late sowings gave better stands than early ones. Establishment is influenced largely by weather following sowing; good seed-bed preparation can reduce but not obviate the effects of unsuitable weather. This is especially marked with pasture sowings.

(iv) *Crop Sequences.*—Yields of a test crop of sorghum were higher immediately following cotton and peanuts than following sorghum, and the same residual effects were observed when the test crop was grown two seasons after, irrespective of the intervening crop.

(v) *Annual Fodder Crops.*—In a growth study of fertilized annual fodder crops, dry matter yields of up to 15,000 lb./acre (Bulrush Millet) were recorded. It appears likely that, at Katherine, advantage can be taken of the high yield potential of late maturing fodders.

(vi) *Native Pastures.*—Native pasture showed a marked response in dry matter yield (up to 250 per cent.) from combinations of N and P with a strong interaction between nutrients.

(vii) *Cattle.*—In a test of the value of buffel grass/Townsville lucerne as a dry season feed, cattle gained 101 lb. between mid-June and mid-November, while a corresponding group on native pasture lost 74 lb. The response of cattle on native pasture to tick control and phosphate supplementation is under investigation, and first-year results show a substantial increase in liveweight gain from both.

(viii) *Nitrogen Cycle Investigations.*—The soil nitrate content under annual and perennial crops and under fallowing is being studied. Tippera clay loam fallowed for three years has a high initial nitrate content at 3-5 feet, and nitrate content in the topsoil fluctuates at low levels during the summer and is higher in winter, both indicating heavy leaching. Down to a depth of 3 feet nitrate is higher under fallow than under crops. A striking stratification of nitrate in the topsoil with a peak at a depth of 1.75 inches has been recorded and is being investigated.

(*b*) *Kimberley Research Station.*—The Kimberley Research Station has a twofold objective. The immediate aim is to determine if irrigated agriculture can be successfully established on the land which might be irrigated from the proposed dam on the Ord River. The long-term objective is to study irrigated agriculture in the tropical monsoonal climate of northern Australia. The search for information on potential crops has dominated the programme until recently, but as the information has accumulated, so the more basic problems of the second objective have become evident.

(i) *Sugar Cane.*—This crop has for some years dominated the Station's programme, and sufficient information is now available to be able to recommend sugar cane as well adapted to the region. In the last harvest, variety POJ 2878 topped the yields with 48.1 tons of cane per acre and 6.6 tons of sugar. Effort hitherto devoted to sugar will now be transferred to rice and safflower, which after sugar have been the most successful crops under trial, and to cotton.

(ii) *Rice.*—Previous work with rice has shown that yields up to 4000 lb./acre can be obtained on experimental plots with the better *indica* varieties in the wet season, and with selected *japonica* varieties in the dry. *Indica* varieties fail badly in the dry season, partly because of sterility; *japonica* varieties yield about half as much in the wet as in the dry season. Two major problems occur with rice, one nutritional and the other an insect pest—the stem borer. The nutritional problem, which is manifested by a marked yellowing and die-back of the leaves, appears to be connected with nitrogen supply. The stem borer problem, which occurs with varying intensity in all tropical rice areas, still requires precise control measures.

Work in progress with rice involves the testing of varieties including a large number of introduced *indica* and *japonica* crosses; investigation of depth of cultivation; fertilizer practices including time of application of nitrogen and nitrogen uptake, and studies on irrigation and drainage.

Harvesting trials have shown that the grain should be stripped as early as possible, for the longer it is left in the field, the greater the breakage on milling. The early stripping at a moisture content of 27-30 per cent. necessitates artificial drying before the grain can safely be stored at a moisture content of about 12-14 per cent.

(iii) *Safflower.*—Erratic yields have been recorded with this crop in the past, but a time-of-planting trial in the 1956 dry season indicated that good yields could be expected from crops planted early. Investigations now in progress are designed to confirm this observation, to provide more information about the agronomy of the crop, and to test further new varieties. The earlier plantings of the 1956 season yielded 2000 lb./acre.

(iv) *Pastures and Fodders.*—The possibility of producing high-quality feed for use in the winter-early spring from mixed pastures and cultivated row crops, with the addition of heavy fertilizer dressings, is being examined.

(v) *Cattle.*—The results of the first year's trial on the liveweight changes in young stock (one to two years) on native pastures in the dry season indicates that steady increases can be maintained with supplementary feeding.

4. CLIMATOLOGY.

(Division of Land Research and Regional Survey.)

The Climatology Unit studies climate-vegetation relationships in order to define and interpret the important elements of climate as they affect plants.

At present a study of the water balance and micro-environment of a spinifex (*Triodia basedowii*) community is in progress near Alice Springs. This involves studying the fate of rainfall in the community, so that it can be determined how much enters the ground and what proportion of this amount is transpired through the plants and evaporated directly from the soil surface. Associated with these determinations are studies of the phenology of the species so that it will be possible to determine how much of any fall of rain is utilized by the plants, how long this water remains in the soil in a state available for plant growth or survival, and what responses occur in the plants as water stress becomes progressively more severe.

Two main series of laboratory experiments are also in progress. The first deals with the significance of the permanent wilting percentage, which has long been regarded as a highly significant soil water constant. These experiments have indicated that, rather than being a constant, the permanent wilting percentage is a variable value dependent on the osmotic characteristics of the plant under study, and on the conditions under which it has been grown, rather than on any soil characteristics. It has been shown that in any one plant the onset of permanent wilting in the leaf tissue occurs at a stress value which approximates that at the point where the diffusion pressure deficit equals the osmotic pressure and there is zero turgor pressure in the cells of the tissue concerned. At this point the rate of growth falls almost to zero on the onset of wilting and has, as a result, considerable significance to any one plant as an indicator of water availability.

A second series of experiments deals with the significance of water absorption directly by the leaves of plants. It has been shown that absorption can be expected whenever a diffusion gradient exists from atmosphere to plant, and that the transfer of the water from the plant into the soil also tends to occur if a favourable gradient exists. These experiments will be extended to examine the significance of dew-fall, particularly in arid areas.

5. ARID ZONE RESEARCH.

(Division of Land Research and Regional Survey.)

As the world's driest land mass the Australian continent has a very large proportion of country in which rainfall is the critical factor limiting productivity. Land use in these areas is mainly dependent upon exploitation of the native vegetation by cattle or sheep grazing. World experience has shown that over-exploitation in such areas results in serious and permanent deterioration of this natural resource. On the other hand, there is also evidence that in some circumstances an improvement in productivity, above that of the naturally occurring plant communities, can be achieved.

The Division has initiated such research at Alice Springs in three main fields: (1) ecological studies of native plant communities to provide basic information in relation to the management and maintenance of native pastures; (2) ecological studies of native and introduced species with the object of improving the pasture vegetation in more favoured sites; and (3) the exercise of some control of normal run-off to achieve more efficient use of rainfall than occurs under natural conditions.

Aided by a grant from the Australian Meat Board the Division and the Northern Territory Administration are collaborating in an investigation of range seeding possibilities with particular reference in the first instance to the use of buffel grass (*Cenchrus ciliaris*). As part of this programme two officers of the Division made extensive collections of seed and information of native species of pasture value, for preliminary testing and study. An area of land on the Animal Industry Branch Research Station is being developed as a nursery and study area. In addition a number of typical land sites within the region are being selected by the regional survey unit for field trials of species and methods.

Establishment trials with buffel grass on one site, a mulga red earth soil, in which monthly sowings over a period of one year were made, have not given successful establishment. Seed germinates following winter and spring rains, but seedlings in no case survived more than six months. No summer rains of consequence have occurred to give summer germinations or assist establishment of winter germinated seeds. A surface mulch and cultivation have both assisted establishment, but responses to superphosphate have not resulted, possibly because of inadequate rainfall.

Soil moisture studies have given a general picture of water storage and length of the drying cycle in relation to atmospheric conditions. Penetration seldom exceeds a few feet, and the moisture is rapidly exhausted to high, but as yet undetermined, tensions. Roots of the dominant native grass *Eragrostis eriopda* appear to be permanent and penetrate to at least five feet.

The study area has a slope of approximately one in 250; intense rainfalls produce water movement on the surface, and up to double the precipitation has been accumulated in the downslope corner by an earth bank surrounding an ⅛-acre plot. The study of moisture storage in relation to natural or induced microrelief offers possibilities for the establishment of improved pastures.

General ecological observations of the mulga communities have been continued, and a second fenced enclosure was erected for the study of range conditions.

A detailed survey of mulga (*Acacia aneura*) and allied top-feed species was commenced to estimate the range of variation within this polymorphic group. Pastoralists have assisted by giving information on the palatability and distribution of the various forms of mulga. Seedling trials have been initiated to assess the value of cotyledons, first leaves, and phyllodes for variety and taxonomic studies.

An additional 800 plant specimens have been collected to facilitate ecological and taxonomic research projects. These include 100 seed voucher specimens of *Acacia aneura* and 400 from a botanically unknown area to the north and north-west of Maralinga, South Australia.

XII. FISHERIES AND OCEANOGRAPHY.

1. General.

The Division of Fisheries and Oceanography is concerned with a study of the aquatic resources of Australia, including whales, the more important commercial fish, crustacea, and shellfish, to ensure their economic use and, where necessary, their management to prevent depletion of stocks. Fundamental to this study is an examination of the environment to ascertain the variations in oceanographic conditions which affect organic productivity and are to a large extent responsible for fluctuations in fish occurrences.

Division of Fisheries and Oceanography.—Some changes were made to research programmes during the year. The investigations at Lake Macquarie for the New South Wales Department of Fisheries have now been concluded. A new group has been organized to undertake basic research on the factors which influence the production of living matter in the sea. The flathead investigations based on Lakes Entrance have been completed, and a station has been established at the fish cannery at Eden for tuna investigations.

At the request of the Fisheries Division of the Department of Primary Industry, Mr. I. S. R. Munro has undertaken the preparation of a handbook of Australian fishes to appear in parts in the *Fisheries Newsletter*. Mr. Munro is also preparing at the request of the Department of Territories a handbook and a check-list of New Guinea fishes.

During the year the Chief of the Division served on the interdepartmental committee set up to deal with the development of Australian fisheries, and attended the conference between Commonwealth and State Fisheries officers in May. Mr. D. J. Rochford attended the Advisory Committee on Marine Sciences in Peru and was elected for a three-year term. Dr. R. G. Chittleborough visited the Netherlands Whale Research Group in Amsterdam, and attended the 8th Meeting of the International Whaling Commission in London and the 13th Congress of the International Association of Limnology in Helsinki.

Dr. J. Bunt of the Australian National Antarctic Research Expedition has been given space and facilities at Cronulla to work on his collections and data from Mawson. A school of marine biology was held in the Division in June and was attended by university students from Adelaide and Sydney.

Alterations have been made to the aquarium building to provide a laboratory and storeroom for ichthyological work. Further extensions to the aquarium have been completed, and an illuminated constant-temperature room has been arranged for rearing organisms used in marine fouling research.

Grateful acknowledgment is given to the following for their co-operation and assistance to the Division during the year: The Royal Australian Navy, the University of Western Australia, the Commonwealth Department of Primary Industry, the State Departments of Fisheries, Nor'West Whaling Company Limited, Whale Products Limited, the Byron Whaling Company, Messrs. Huddart Parker, Burns Philp, Adelaide Shipping Company, and the Western Australian State Shipping Service.

2. Operations of Research Vessels.

(Division of Fisheries and Oceanography.)

(*a*) *F.R.V.* Derwent Hunter.—Cruise DH/356 was a tuna long-lining cruise off the New South Wales coast. Cruise DH4/56 was a cruise in Bass Strait to examine the correlation between the barracouta fisheries of the area and the fluctuations of krill and to determine any relationship between barracouta and water masses of the area. For cruise DH5/56 the ship was loaned to the Division of Meteorological Physics. Cruise DH6/56 was an oceanographical cruise to New Zealand, thence to Norfolk Island, and back to Sydney. Cruises DH1/57 and DH3/57 were hydrology cruises off Port Hacking, DH2/57 was a tuna long-lining cruise off the east coast of Tasmania, and cruise DH4/57 was a cruise in Bass Strait, again concerned with baracouta.

(*b*) *F.R.V.* Gahleru.—This was put into commission at the end of July, 1956, following the installation of a new engine. Ten cruises were completed to the end of December when specimens of *Pinctada maxima* were collected and "stockpiled" at the Mainland Grounds. One cruise was made to Groote Eylandt to tag shell for growth studies. During the wet season short trips were made to mainland grounds to collect gonad samples from the shell stored there. Five cruises were made after April to collect further supplies of *P. maxima*.

3. Fisheries Biology.

(Division of Fisheries and Oceanography.)

(*a*) *Whales.*—A new type of whale mark was developed in Perth and tested successfully upon dead humpback and sperm whales at Carnarvon and Albany stations.

During the 1956 humpback whaling season, material required for research was collected by members of this Division or by whaling inspectors at all five Australian whaling stations. Considerable marking was carried out, mainly on the east coast of Australia.

At the close of the humpback whaling season, material collected at Australian whaling stations was examined, and catch returns from Australian stations and also from Antarctic areas IV. and V. were analysed. A report upon the recent catches of humpback whales from the stocks known as Group IV. and V. was prepared for the 9th Meeting of the International Whaling Commission. It was shown that the constitution of the catch on the western coast of Australia during 1956 was more favourable than that of the 1955 season. A high degree of selection was maintained on this coast in both seasons; the improvement in the 1956 catch was due mainly to the closing of the station at Point Cloates and the concentration of catching effort and equipment at Carnarvon. In Antarctic area IV. the composition of the catch of humpback whales in 1956 showed a little improvement in some, but not all, aspects when compared with the catch in 1955, but the 1956 catch did not compare favourably with the corresponding catch from the western coast of Australia.

On the east coast of Australia, the catches in 1955 and 1956 were of considerably better composition than in previous years, apparently as a result of more careful selection of larger whales. However, in the corresponding sector of the Antarctic (area V.), where the selection factor has been relatively constant from year to year, the composition of catches declined markedly in 1955 and 1956. These changes do not reflect favourably upon the condition of this stock of humpback whales.

(*b*) *Sea Fish.* (i) *Barracouta* (Thyrsites atun).—The main aims of the barracouta programme since July, 1956, have been (1) to test the hypothesis that annual fluctuations in the success of the barracouta fisheries of Bass Strait depend mainly upon corresponding fluctuations in the availability of *Nyctiphanes australis* (krill) in the coastal waters in summer and autumn, (2) to determine the possibility of a correlation between the water masses, plankton, and occurrences of barracouta in Bass Strait waters, and (3) to attempt to determine the whereabouts of *Nyctiphanes* and barracouta when they are not plentiful in Bass Strait coastal waters.

This work has been carried out from the F.R.V. *Derwent Hunter*, the first cruise being during October-November, 1956, and the second during May-June, 1957. Cruises consisted of hydrological and planktological sampling of the Bass Strait area, together with slow-speed trolling for barracouta. It is now apparent from these two cruises that it is not possible, with existing facilities, to carry out the extensive water and plankton sampling programme without seriously curtailing the periods devoted to fishing for barracouta, and for this reason it is intended that the barracouta programme be replanned.

The October-November cruise produced very few barracouta. Those from the western sector of the Strait were feeding predominantly on krill while those from the eastern sector were feeding predominantly on fish and particularly on anchovy. However, though euphausiids were available to barracouta in both sectors (as determined from plankton sampling), they were probably available in greater quantities in the eastern sector.

The results obtained from the recently completed autumn cruise seem to indicate that, with the disappearance of food such as anchovy, the barracouta feed almost exclusively upon euphausiids. Though very few barracouta were taken on this cruise, those with stomach contents had been feeding on euphausiids.

Sampling of the Victorian commercial barracouta fishery was carried out during the first half of the year, mainly directed towards a study of the feeding habits of the fish.

(ii) *Trawl Fish.*—Market sampling of tiger flathead has been continued at Sydney Fish-market. Approximately 12,000 length measurements were recorded, and 1,200 fish were examined for gonad stages, stomach contents, condition, and age determination.

The investigation of the Lakes Entrance Danish seine fishery was concluded in January, 1957. During this year 12,000 fish were measured, 600 were examined, and 1,900 fish were tagged.

(iii) *Tuna.*—Two long-lining cruises were made, the first in August-September, 1956, the second in March-April, 1957. Data from the first cruise—catch results correlated with water mass distribution—support the hypothesis that the tuna species are segregated according to water mass distribution, and in particular southern bluefin tuna are controlled by degree of vertical mixing between the sub-Antarctic and the Central Tasman water masses.

(iv) *School Shark* (Galeorhinus australis).—Twenty-four tags from school sharks have been returned during the year. Two were from sharks tagged 23 and 61 weeks earlier by Port Lincoln fishermen and recaptured in South Australian and Tasmanian waters. The remaining 22 tags were from sharks that had been free from three to fourteen years.

(*c*) *Estuarine Fish.* (i) *Lake Macquarie Investigations.*—The field work on this project finished on March 31. Preliminary analysis of the last twelve months' work shows nothing inconsistent with the interim conclusions presented in previous reports.

Lake Macquarie (42 square miles in area) has been mapped in terms of animal density in three ecological areas. The weed fringe comprises 24 per cent. of the area and is characterized by plant growth and a diversity of animal forms, the slope is 15 per cent. of the area and dominated by filter feeders, and the grey mud floor is 60 per cent. of the area and occupied by a few species of bottom feeders. Oxygen deficiency at flood time may be an important factor in limiting bottom dwelling animals. In an experiment to test survival it was found that *Mytilus planulatus*, usually found in areas not exposed to oxygen shortage, died after a few days, while *Trichonya hirsuta*, typical of Lake Macquarie, lived for three weeks in water at Eh as low as 200 mV and of high H_2S concentration.

(ii) *Western Australian Estuarine Fish.*—Flathead, kingfish, salmon trout, tailor, and ruffs are carnivorous, and whiting and snapper largely so. Bream, skipjack, and cobbler are omnivorous; garfish and yellow-eye mullet are largely herbivorous but also take small animals. The Perth herring is iliophagous. Of 376 stomachs containing fish as food, only ten contained commercial species of fish. Small molluscs, amphipods, shrimps, polychaet worms, and chironomid larvae are the important animal foods ingested. Filamentous algae, eelgrass, and diatoms provide the principal plant elements in the diet.

A study of the breeding seasons and the size at maturity of the same species is nearing completion. Bream spawn from late winter to spring; cobbler and skipjack in spring; garfish and Perth herring over the spring and summer; flathead, sand whiting, and yellow-tail are summer spawners; yellow-eye mullet spawn in water.

(iii) *Barramundi* (Lates calcarifer).—River systems with large catchment area, low run-off, but permanent flow provide the best environment for barramundi. Growth is very variable depending upon the food available in the winter trophic phase. Spawning takes place in water of high salinity adjacent to the river mouths. The spawning season is extended over the summer with two major spawnings, one at the beginning of the rainy season and one at the end.

(*d*) *Freshwater Fish.* (i) *Trout* (Salmo *spp.*) *Investigations in Tasmania.*—Routine sampling of the spawning runs continues.

(ii) *Fish Culture Investigations in Tasmania.*—The study of the biology of the tench (*Tinca tinca*) has been completed. The results indicate that the tench is suitable for cultivation in farm dams, and information is now available on its temperature tolerance, respiratory physiology, food habits, and growth rate.

Fish production has been measured in eight farm dams, and the best yields compare favourably with those obtained in unfertilized fish ponds in Europe and the United States of America.

(*e*) *Crustacea and Shellfish.* (i) *Western Crayfish* (Panulirus longipes).—The analysis of statistical data on this species for the period 1943-56 at Houtman Abrolhos was continued. Underwater observations and collections of "white" crayfish during November and December, 1956, have confirmed previous opinions that these are the same species as the commercial Western Australian crayfish *Panulirus longipes.* Large numbers of crayfish were found in areas close to the shore at Geraldton in mid-November. Of the sample collected (37), 19 had already moulted and possessed new soft white shells, and the remainder were in a pre-moult condition with this new soft white shell beneath the old hard red shell.

The carapace lengths of these animals ranged from 2.7 to 3.5 in., and the gonads of all were immature. Twenty-eight undersized crayfish (1.9-2.7 in.) were also taken at that time. Sixteen possessed new, soft, red shells while the other twelve were pre-moult animals with an old, hard, red shell covering the new, soft, red shell.

The late November-December "white" crayfishery is almost entirely based on the capture of recently moulted, pale coloured, immature crayfish, ranging in size from 2.7 to approximately 3.5 in. in carapace length. It is also apparent from the recapture of undersize white crayfish which were previously released in December, 1954, that individual crayfish may be taken as pale-coloured "whites" in three consecutive December periods. Mean carapace measurements of the recaptured "whites" indicate an annual mean increment of 0.3 in. in carapace length during this phase.

Frequent surface plankton hauls to determine larval distribution were made in several areas along the Western Australian coast from March, 1956, to April, 1957. These included the Abrolhos Islands, Rottnest Island, and two long coastal samples from Fremantle to Shark Bay on the P.V. *Lancelin,* and from Fremantle to Onslow on the H.M.A.S. *Fremantle,* in March, 1957.

Both day and night hauls were made during these latter two cruises, but larvae which had been released earlier in January and February could not be collected in these nets. Only one successful haul of *P. longipes* larvae was made 65 miles west of Fremantle, from H.M.A.S. *Junee,* when three late stage phyllosoma were collected. The age of these late stage phyllosoma is estimated to be ten-twelve months, as the majority of the larvae are released from females either in November at the Abrolhos Islands or during January in various coastal areas.

Specimens of the recently settled transparent puerulus stage were collected from commercial craypots at Geraldton and Dirk Hartog Island in December (also reported from Lancelin Island), and additional specimens were irregularly collected off Dirk Hartog Island in January, February, March, and as late as the middle of April. It is surprising that the supposedly surface-dwelling late phyllosoma and early puerulus stages were not taken in either day or night hauls along the coast in March.

(ii) *Southern Crayfish.* (Jasus lalandii.—During January, 1957, 749 undersized crayfish were tagged and released at two positions at Cape Sorell on the west coast of Tasmania. Of the 115 crayfish tagged the previous year in this locality, five females were recaptured and the mean growth increment was determined at 0.23 cm.

(iii) *Pearl Oysters* (Pinctada *spp*).—A further 1,000 specimens of *Pinctada maxima* were tagged and measured at Groote Eylandt in November. These will be lifted and remeasured after twelve months. The study of the gonads of this species has been continued.

Attempts to collect spat of *P. maxima* have again failed. A number of collectors of a size and type comparable to those used by Crossland for *P. margaritifera* in the Red Sea were laid out on the Mainland Grounds both on the bottom and at the surface. The surface collectors received heavy sets of *P. albina* (*sugillata*), and *P. fucata,* and a few individuals of *P. chemnitzi,* but no *P. maxima.* The bottom collectors received no spat.

Success in pearl culture has been attained with the production of several half pearls and some graft pearls in *P. maxima.*

(iv) *Scallops.*—The commercial catch was sampled during the 1956 season, and fishing intensity was determined. These figures are now available for comparison with those from previous years.

(v) *Oysters.—Sydney Rock Oyster* (Crassostrea commercialis).—No work could be carried out on the problem of winter mortality as, for the third successive year, it failed to appear in Georges River. Its absence is believed to be correlated with the heavy rainfall experienced in these years. It is probable that the mortality will reappear after a dry winter. When this occurs a new study of the mortality will be made.

Pacific Oysters (Ostrea gigas).—The Pacific oysters in Mallacoota Inlet were seen by eye-witnesses to spawn on two occasions, once in November, 1956, and again in January, 1957. Examination showed a few spat settled from the November spawning, but so far no trace has been found of spat from the later spawning which was believed to be greater.

4. ICHTHYOLOGY.

(Division of Fisheries and Oceanography.)

(*a*) *Reference Catalogue of Australasian Fish.*—This catalogue has been kept up-to-date, and its contents have been revised on the basis of original investigation in connexion with the preparation of the handbooks on Australian and New Guinea fishes.

(*b*) *Reference Collections.*—Progress has been made in the reorganization of existing fish collections with a view to providing an auxiliary aid to identification processes. Use of collections has been facilitated by the recent construction of a properly indexed store-room.

(*c*) *Check-list of New Guinea Fishes.*—The check-list of fishes from the New Guinea region has been completely revised for publication.

(*d*) *Handbook of New Guinea Fishes.*—Work has continued on a revised form of an illustrated handbook of the fishes of the Australian Territory of Papua and New Guinea. This project is being carried out for the Department of Territories.

(*e*) *Handbook of Australian Fishes.*—The first twelve numbers of this illustrated handbook have been published as monthly supplements to the *Australian Fisheries Newsletter,* beginning in July, 1956. The thirteenth number is now in press, which brings the total pagination to 56 and the number of species described to 404, most of which have been illustrated.

(*f*) *Fish Eggs and Larvae.*—Some further experience has been gained in the rearing and feeding of naturally spawned post-larval fiish. A programme of collection of sexually mature adult fishes from Port Hacking and of demersal fish by trawling in neighbouring shelf waters has been initiated.

5. HYDROLOGY.

(Division of Fisheries and Oceanography.)

(*a*) *Oceanic.*—Between July, 1956, and June, 1957, F.R.V. *Derwent Hunter* completed three sections off Port Hacking and a cruise to New Zealand.

The New Zealand cruise had to be curtailed because of bad weather on the southern leg and loss of a rudder on the northern, so that its results are not as conclusive as the original schedule would have achieved. However, on the southern leg it was clearly established that warmed sub-Antarctic waters can be found to the north of the main tropical convergence in the southern Tasman Sea during summer. There appears to be a secondary convergence between these waters and those of the northern Tasman Sea along a front extending south-west from Cook Strait to south of Tasmania. The mode of summer assimilation of the south-west Tasman water mass to the east of Tasmania was also established. On the northern leg the depth and western limits of the east central New Zealand water mass were charted. Evidence of a flow at intermediate depths of the south-west Pacific water mass into the Tasman Sea to the north-west of New Zealand was also found on this cruise.

(*b*) *Coastal.* (i) *New South Wales.*—Sampling at selected coastal stations has been continued.

(ii) *Tasmania.*—Stations are now worked at Maria Island and St. Helens on the east coast, Port Sorell and Stanley on the north coast, and Cape Sorell on the west coast. The collection of surface samples was carried out during the year by M.V. *Taroona;* in addition, the services of a new vessel were enlisted to cover the area from the west coast of Tasmania to the mouth of the Murray River in South Australia.

(iii) *South-west Australia.*—Hydrological work in this area ceased early in 1957. Analysis of surface samples collected during the year by M.V. *Duntroon* strengthened the hypothesis that the winter movement down the west coast normally extends beyond Albany. In the latter region the warm water mass is confined to the onshore region; there is a marked decrease in temperature across the continental shelf. Returns of drift bottles released in the south-west coastal region indicate that this belt of warm onshore water is split in spring by a system which moves north along the west coast and east along the south coast, and which divides in the region of Cape Leeuwin.

(*c*) *Estuarine. Lake Macquarie.*—Field work on this project concluded in December, 1956. In the later stages of the investigations emphasis was placed on a study of the circulatory features of the lake. It is now clear that wind direction, intensity, and duration affect the north and south movements of surface and subsurface waters. These wind patterns, associated with the state of the external tides, exert a great influence on the water levels within the lake.

A continuous tide recorder, installed at Mark's Point, showed that changes in water level over a period of several tides can exceed the tidal amplitude, which is only a few inches. The connexion to the sea is a shallow and winding channel, which acts as a valve between the sea and the lake, and the external tide makes some contribution to the lake only if the high water reaches a certain level.

6. PHYSICAL OCEANOGRAPHY.

(Division of Fisheries and Oceanography.)

(*a*) *Instruments.*—An instrument for recording temperature, chlorinity, and depth in the range 0-1,000 m. was developed recently in the Division of Electrotechnology. This instrument has been tested at sea on four cruises during 1956-57.

A smaller instrument for the measurement of temperature and chlorinity, also developed in the Division of Electrotechnology, has proved successful in both laboratory and field use. Thirteen of these instruments have been made commercially.

(*b*) *Mean Sea-level.*—Monthly mean sea-levels at tide gauges on the coast of New South Wales have been studied in relation to atmospheric pressure and the density of the upper 600 m. of sea-water. The available information on density was not sufficient to establish a clear relationship between water density and sea-level, but there appeared to be a connexion between sea-level and winds parallel to the coast.

(*c*) *Volume Transport of the East Australian Current.*—The routine calculation of surface currents and volume transport parallel to the coast off Sydney has begun. The calculations are made from the water densities in the upper 1,000 m.

Surface currents are also being measured directly by means of the electrical voltage induced in a length of cable trailed behind the ship, the induced voltage being due to the cable cutting the vertical component of the Earth's magnetic field.

(*d*) *Relation between Volume Transport and Wind Stress.*—The possibility of calculating the volume transport parallel to the coast from the stress of the wind on the surface of the Tasman Sea is being investigated.

7. PRODUCTIVITY.

(Division of Fisheries and Oceanography.)

It is hoped that the knowledge gained from the research work of the newly organized group will enable the productive areas in Australian waters to be recognized and the factors involved in production to be determined; as a final step it is hoped that this knowledge will be used to allow human intervention to bring present unproductive areas into production.

One of the basic steps in the production of living matter in the sea is the interaction between sunlight and the chlorophyll in marine plants to allow carbon dioxide in the water to be converted into plant and animal tissue. As a first step in the investigation, studies are proceeding on this interaction. Fortnightly observations on chlorophyll and light intensity have been made at the 50 and 100 m stations off Port Hacking.

The use of membrane filters for the removal of chlorophyll-bearing organisms from sea-water has been investigated, and it was shown that they are unsuitable in Australian onshore waters which are often low in chlorophyll but which can contain appreciable amounts of inorganic sediment which block these filters.

8. PLANKTOLOGY.

(Division of Fisheries and Oceanography.)

(*a*) *Bass Strait.*—A cruise was made in this area in October, 1956, by the *Derwent Hunter* in conjunction with the barracouta programme. This, together with the results of the previous year's cruise at this time, showed that there was a stable inshore plankton, and a characteristic shallow water offshore plankton which may be displaced by an invasion of oceanic plankton. This invasion coincided with the easterly movement of a large tongue of water across central Bass Strait. Greatest plankton concentrations were found round the advancing periphery of this water mass. The krill, *Nyctiphanes australis,* which is barracouta food for a large part of the year, appears independent of water movement. The early larval stages favour inshore areas, but the later stages, including adults, may occur in any region. In November, 1955, they were most abundant in the western half, whereas in October, 1956, they were in the eastern regions of Bass Strait, where the majority of barracouta were taken. The large copepod, *Calanus helgolandicus*, which is important as food for anchovies and pilchards, is also largely independent of water movements.

(*b*) *Eden.*—Immediately after the Bass Strait cruise in October, 1956, the plankton characteristics of a thermocline just off Eden were examined. The thermocline was associated with a tongue of cold water advancing northwards from Bass Strait. This water mass may be associated with the major easterly movement found in Bass Strait at this time of the year. The plankton was that typical of the shallow-water offshore areas of Bass Strait, and its abundance per unit volume of sea-water was approximately three times that on the other side of the thermocline. This cold water mass with its associated abundant plankton is closely associated with the abundance of tuna and barracouta at Eden. The plankton concentration attracts the smaller predators such as anchovies which are preyed on by tuna and barracouta.

(*c*) *Tasman Sea.*—The results of the Derwent Hunter cruise to New Zealand, between December, 1956, and February, 1957, combined with those of the cruise to Noumea in November-December, 1955, enabled the summer distribution of zooplankton in the Tasman Sea to be worked out. The plankton composition over the entire area was remarkably uniform, the species being predominantly subtropical. In the vicinity of New Caledonia, tropical species became more abundant, but were additions to, rather than replacements of, the Tasman Sea fauna. On the other hand, south of 40° S. latitude, colder water species began to replace those of the Tasman Sea. Greatest zooplankton concentrations occurred between the Australian coast and Lord Howe Island, from the latitude of Brisbane to that of northern Tasmania, especially in the eastern Australian current. Here the quantity of zooplankton per unit volume of sea-water was several times that of the rest of the Tasman Sea, which generally has a poor standing crop of plankton.

(*d*) *Jibbon.*—Regular collections over two years off Port Hacking show that the maximum abundance of zooplankton is reached in summer. If the spring salp swarm is heavy, as in 1955, the late spring increase is interrupted, other zooplankton becomes scarce until the salp swarm is passed, and the maximum is not reached until late summer. In 1956, the salp swarms were not large, did not persist, and the maximum was reached by midsummer.

9. MICROBIOLOGY.

(Division of Fisheries and Oceanography.)

Microbiological studies on Lake Macquarie were completed during the year, though laboratory work on collected material has continued. As a general conclusion it may be stated that the blue muds of the lake bottom have low microbial activity compared with that of the sea-grass community. This means that the latter, together with the phytoplankton, provide the plant material required for animal production in the lake, although some at least of the blue muds are within the photic zone.

Culture work on oceanic phytoplankton organisms has continued, and a number of microorganisms have been grown in culture.

10. MARINE FOULING.

(Division of Fisheries and Oceanography.)

Studies on methods of obtaining, rearing, and observing the reactions of settling fouling larvae have been continued. Larvae of the bryozoans *Bugula neritina* Linne and *Watersipora cucullata* Bush, two prominent fouling organisms in Sydney Harbour, were both found to have a pelagic and a searching phase before settlement. Settlement could be delayed for some time if a suitable substratum was not available, but a further prolongation of this resulted in larvae attempting to settle regardless of the nature of the substratum. This was under non-toxic conditions. In toxic copper solutions, Bugula larvae showed reactions more complicated than have been recorded previously. At some concentrations larvae settled at a faster rate than the controls but at others it was decidedly slower. The relationship between concentration and reaction is being followed further.

Settling stages of two bryozoans, *Bugula avicularia* Linne and *Schizoporella unicornis* (Johnston), and two species of tubeworm, *Spirorbis*, have now been obtained in the laboratory and are being considered, along with others, for experimental work. In order to feed larvae with indirect development (barnacles, other tubeworms, bivalve molluscs), ways of providing animal and plant nannoplankton as a source of food are being investigated. A mass culture unit has been built to grow flagellates, algae, or diatoms under controlled lighting, temperature, and media conditions, and to feed these into tanks of larvae.

Studies on the systematics, distribution, and seasonal intensity of fouling, which have been based on plate exposures along the New South Wales coast, have been terminated. The main fouling organisms in Sydney Harbour are considered to be the barnacle *Balanus* (*Balanus*) *amphitrite* var. *cirratus* Darwin; the tubeworms *Hydroides norvegica* Gunnerus and *Spirorbis* sp.; the bryozoans *Watersipora cucullata* Bush, *Bugula neritina* Linne, and *B. avicularia* Linne; and the mussel *Mytilus planulatus* Lamarck.

XIII. FOOD.

1. GENERAL.

The preservation of food is an increasingly important link between primary industry and the consumer market. There is a growing awareness of the part which science and technology can play in reducing wastage, improving quality, and generally raising the efficiency of Australia's food processing industries. The complex constitution of foodstuffs of all kinds, especially meat, dairy products, and fruits, calls for fundamental studies based on physics, chemistry, botany, and bacteriology to ensure the elimination of processing and storage conditions which tend to their deterioration. As a major food producing country situated far from the main food importing nations, and with its own population centres separated by long distances, Australia has a special interest in the preservation of foodstuffs during transport.

The Organization's work on food is undertaken chiefly within the Division of Food Preservation and Transport with its main laboratories at Homebush, New South Wales, and branch laboratories at Brisbane, Queensland (meat); West Gosford, New South Wales (citrus fruits); Hobart, Tasmania (fish, apples, and berry fruits); and at the Botany and Biochemistry Departments, University of Sydney (plant physiology and physical chemistry). The work of the Division is described in Sections 2-11 of this Chapter. Work on the manufacture of dairy products is carried out by the Dairy Research Section at Highett, Victoria (*see* Section 12 of this Chapter). The major objectives of the Dairy Research Section include a better understanding of the flavour chemistry of dairy products, the better utilization of non-fat milk solids through the development of new food products, and the mechanization of cheese manufacture.

Work on dried vine fruits is in progress at the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria (*see* Section 13 of this Chapter).

Division of Food Preservation and Transport.—There have been no major changes in the Division's research programmes during the year.

The new fly breeding laboratory and fruit examination shed were officially opened in August at Gosford, where the co-operative investigations with the New South Wales

Department of Agriculture on the killing of larvae and eggs of the Queensland fruit fly in citrus fruits have continued to be a major part of the research programme.

At the Tasmanian Regional Laboratory the construction of the food processing laboratory was completed in May. The facilities and processing equipment now available at this annexe will enable canning investigations to be intensified.

Co-operative investigations with the Low Temperature Research Station, Cambridge, on the effects of the level of acidity in beef muscle and of the period of delay before the onset of rigor mortis on the quality of beef after freezing and thawing have been completed, and the research worker seconded from Cambridge has returned to England.

In the field of plant physiology and fruit storage, programmes have been devised for co-operative research in collaboration with investigators at Cornell and Rhode Island Universities (United States of America) and the California Institute of Technology.

The Division has continued to provide research facilities for a number of guest workers, including junior and senior Fellows appointed under the Colombo Plan.

Dairy Research Section.—The Engineering Section has now completed the fabrication of the prototype curd-fusing or " cheddaring " machine which has been conceived and developed in the Section. This machine, which covers the most difficult step in the mechanization of the manufacture of Cheddar cheese, is now giving most promising results.

During the year a number of new techniques have been adopted in the investigational work of the Section, including the use of gas chromatography, in the field of flavour chemistry.

The Australian Dairy Produce Board has contributed a further sum of £3,000 towards the cost of the cheese mechanization programme. The Board has also borne the cost of a commercial-scale butter storage experiment.

The Officer-in-charge (Mr. G. Loftus Hills) and Mr. J. Conochie attended the XIVth International Dairy Congress in Rome. After the Congress the Officer-in-charge attended two F.A.O. conferences in dairy problems, and then on behalf of the Australian Dairy Produce Board made a survey of the shipping and handling of Australian cheese in the United Kingdom.

Two research workers from overseas came to spend a year with the Section, one a Colombo Plan Fellow from Manila, the other a British Memorial Fund Fellow from the United Kingdom.

A symposium on casein was held in the Laboratory in March. Papers were given by officers of the Section, the Division of Food Preservation and Transport, the University of Sydney, and the South Australian Department of Agriculture.

The Section has continued to prepare freeze-dried starter cultures for distribution to cheese and casein factories, through the agency of the various State Departments of Agriculture.

2. PHYSICS.

(Division of Food Preservation and Transport.)

(*a*) *Rail Transport.*—Work in collaboration with the Division of Horticulture, Queensland Department of Agriculture and Stock, on a fan car, which was mentioned last year, has been continued. The data have been analysed and a report has been circulated.

(*b*) *Drying of Rice.*—When rice grown in the Murrumbidgee Irrigation Areas is allowed to dry out thoroughly before harvest, losses through breaking of grain during milling are often severe. It has been shown by officers of the New South Wales Department of Agriculture and others that the Californian practice of harvesting at about 20 per cent. water content or higher and drying the rice gently before or during storage will result in greatly reduced milling losses. Consequently there is keen interest in the area in drying techniques, particularly in the drying of paddy rice stored in bulk by aeration with unheated air, and the Division was invited to undertake a study of the physics of this process in collaboration with the Rice-growers' Co-operative Mills, the Rice Marketing Board of New South Wales, and the New South Wales Department of Agriculture. The object of the work was to reach a fuller understanding of the processes going on in the rice during aeration in order to provide data necessary for the design and efficient operation of large installations for bulk storage and drying of paddy rice.

Detailed measurements were made in three types of bin, pilot scale or larger, and less complete observations were also made in a large shed equipped for bulk storage with aeration. Some laboratory measurements were carried out to supplement the field work. The analysis of the experimental data is not yet complete.

(*c*) *Evaporation from Foodstuffs in Cool Storage.*—The study of the evaporation properties of apples has been continued, and measurements have also been made with apple cucumbers because they are geometrically similar to apples but have much greater rates of evaporation.

A further series of measurements with apples grown in different districts has confirmed the consistency of the variations in evaporation properties which were reported previously.

(*d*) *Canning Processes.*—The effect of the variation with temperature in the thermal properties of foods on the forms of heating and cooling curves has been studied in some detail, and a paper summarizing the results is being prepared for publication.

(*e*) *Stowage of Eggs on Shipboard.*—Measurements on three ships were carried out on behalf of the Refrigerated Cargo Research Council to study the effects of different current practices on the rate of cooling of the eggs in cases to carriage temperature.

(*f*) *Freeze Drying.*—In collaboration with the Microbiology Section, a laboratory freeze drier for bacteriological investigations has been designed and constructed. A good deal of success was achieved in providing closer and more positive control of drying conditions than was possible in earlier designs of equipment.

(*g*) *Colour Measurement.*—An objective measurement of the colour of some foodstuffs has been obtained by determining spectral reflectance curves and tristimulus values. The data for a range of samples of tomato purees are being studied to find a convenient method of colour grading.

3. FOOD CHEMISTRY.

(Division of Food Preservation and Transport.)

(*a*) *Control of Superficial Scald.*—Superficial scald is a serious disorder of stored apples, and there is evidence that it is caused by volatile substances produced by the fruit itself. However, experiments with volatile substances so far identified only gave significant increases of scald with excessively high concentrations. Attempts to identify other natural volatiles, particularly hydrocarbons, are being continued.

As the composition of the oil in impregnated wraps (a standard method of control) may be critical, the effect of a number of mineral and vegetable oils is being investigated. A method of determining diphenylamine, an effective inhibitor of scald in the fruit tissue, is being developed. The effect of substances related to diphenylamine is being investigated.

(*b*) *Natural Coating of Apples.*—The storage behaviour of fruit is affected by the composition of its internal atmosphere, which in turn is determined by the resistance of the natural coating to gaseous exchange. Work on the unsaturated acids of the oil fraction of the natural coating is complete, and the unsaponifiable portion is being investigated. The volatile, wax, and " cutin " fractions are also being studied.

(*c*) *Lipid Metabolism of Avocados.*—A study of the chemical changes in avocados during maturation and storage was undertaken. Considerable fat synthesis occurs during the maturation of this fruit, and an understanding of the mechanism is being sought. The fat was shown to increase at the expense of water-soluble constituents.

(*d*) *Studies on Fatty Acids.*—Studies on techniques of separating and characterizing fatty acids were continued. These include the refractive index-density diagram and isomerization of polyene acids with potassium *t*-butoxide.

(*e*) *Anaerobic Decomposition of Ascorbic Acid.*—Further data were obtained on the production of furfural and carbon dioxide during the anaerobic decomposition of ascorbic acid (vitamin C) at 100° C. One other product of the decomposition is being investigated.

(*f*) *Water-soluble Constituents of Fruit.*—The identity of the amino acids, organic acids, and sugars in apricots and peaches has been studied to provide basic data for work on the chemistry of non-enzymic browning in dried fruits. Details of the identity of the organic acids and sugars have been given in previous reports, and this work has now been completed with the publication this year of a paper describing the identification of the amino acids. The same eighteen amino acids were found in both apricots and peaches. Except for a much lower concentration of proline in peaches, the amino acids were present in similar proportions in the two species. Traces of seven other amino acids were also found.

Apricots have been used for the quantitative determination of amino acids and organic acids by means of elution chromatography on columns of ion exchange resins.

(*g*) *Chemistry of Non-enzymic Browning.*—Browning in dehydrated foods is most frequently caused by chemical reactions involving the amino acids, organic acids (if present), and sugars. The investigation of the reaction products in browned freeze-dried apricots and peaches was continued, and the identification of the cationic constituents was completed. For this purpose a range of 1-(*N*-amino acid)-1-deoxyfructoses was synthesized, and their order of displacement on cation exchange columns and their R_{glucose} values were recorded. The glycerine and β-alanine compounds were obtained crystalline and are the first crystalline compounds of this class to be described. The browned freeze-dried fruit contained eleven 1-(*N*-amino acid)-1-deoxyfructoses, two 2-(*N*-amino acid)-2-deoxyglucoses, nine by-products of unknown constitution formed from aspartic acid and asparagine and glucose, and three compounds formed from ammonia and glucose.

The anionic fraction of the browned fruit contained sucrose, glucose, fructose, and sorbitol mono-esters of malic acid and some sugar mono-esters of citric acid. The free amino acid or organic acid lost was approximately equal, on a molar basis, to the reaction products formed, but as much as 7 per cent. of the total sugar could not be accounted for and was, therefore, available for the formation of brown pigments.

The investigation of chemical reactions in model systems has been continued and kinetic studies of the reaction between glucose and glycerine are in progress.

(*h*) *Urea and Heat Denaturation of Proteins.*—The comparative study of the denaturation of proteins by heat and urea is being continued. The urea denaturation of the iron binding protein, conalbumin, of egg white has been studied. The iron-conalbumin complex is much more resistant to urea than the iron-free conalbumin. Work on the heat denaturation of ovalbumin was also continued. The effects of temperature and salt concentration on the rate of denaturation and aggregation was studied with the use of the techniques of polarimetry, viscometry, and sedimentation velocity.

(*i*) *The Chemistry of Casein.*—During the year a paper was published by Waugh and von Hippel in which they fractionated milk by using calcium ions. They found an additional casein component, kappa-casein, which they claim is involved in the action of rennet on casein. In order to check this claim and to further studies on the heterogeneity of casein and the mode of rennet action, a thorough fractionation of casein has been made in this Laboratory by a variety of techniques. These fractions are now being studied, as part of a research programme being carried out on behalf of the Organization's Dairy Research Section.

(*j*) *The Effect of Freezing on Proteins.*—Further studies on the individual effects of freezing using well-defined protein systems and freezing conditions were continued. A method was developed for preparing concentrated, homogeneous actomyosin solutions from fresh black-fish muscle. Starvation of the fish and storage of the muscle or the solution were found to change the state of aggregation of the actomyosin, as judged by its behaviour in the ultracentrifuge. Preliminary work on the effects of freezing actomyosin sols and gels showed that considerable changes in particle size and shape may occur.

(*k*) *Polarography.*—As a result of ten years' experience in the Division on the technique of polarography, a review of polarographic methods and their use in trace analysis is being prepared.

(*l*) *Infra-red Spectroscopy.*—The work on limonin, the bitter principle of oranges, malvalic acid, and *bicyclo*-octane have been completed.

4. MICROBIOLOGY.

(Division of Food Preservation and Transport.)

(*a*) *Water Relations of Microorganisms.*—Experimental work in this field has been resumed following the return of an investigator from study in England. As the requirements of microorganisms for water and salts are inevitably closely linked, recent work has been concerned particularly with comparative studies of bacteria differing widely in their tolerance to sodium chloride. For two species which are of commercial importance on salted meats quantitative estimates have been obtained of the rates of growth at various salt concentrations. The most salt-tolerant strain grew only slowly at the optimum salt level.

Earlier studies had shown that the internal solute concentration of bacterial cells followed fairly closely the solute concentration of the medium in which they were grown, and that cells grown in concentrated solutions rapidly lost some of their internal solutes when the cells were transferred to dilute solutions. The changes which follow the transfer of cells from dilute to concentrated solutions have now been studied in some detail. Adjustment to the new environment has occurred only in the presence of nutrients, and then only after a period of delay. Growth did not occur during the period of adjustment, but was resumed immediately after osmotic equilibration was complete.

A review dealing with both the basic and applied aspects of microbial water requirements has been published.

(*b*) *Bacterial Spores.*—Experiments designed to explain the great diversity in the heat resistance of the spores of different species of bacteria have confirmed the earlier finding that spores with a low resistance in dilute aqueous solutions had their resistance greatly exalted when they were heated under substantially dry conditions. The increase in heat resistance brought about by controlled drying was much less for spores that had a high resistance in dilute solution. A preliminary report of these results has been published. Further experiments have shown that the large temperature coefficients which are characteristic of spore destruction in dilute solutions were very much smaller when the spores were heated in substantially dry conditions. The hypothesis that heat resistance in bacterial spores is associated with the maintenance of relatively dry conditions within the intact spore has so far received only limited support from experiments on the permeability of the spores to water. These experiments—in which dilute solutions of heavy water were used—have shown, at least for some spores, that a small fraction of the water in the living spore did not mix with external water. The amount of this non-mixing water was reduced in spores which had been killed by heating. Difficulties in the purification and estimation of heavy water have not yet been completely overcome, and further experiments are needed for a more rigorous testing of the relationship between permeability and the extent to which viability is reduced by heating.

(*c*) *Drying of Microorganisms*.—Further experiments on the storage of dried microorganisms have provided additional support for the theory that death in the dry state may result from reaction between carbonyl compounds and amino groups on cellular proteins. As many factors affect the rate of death, rather large factorial experiments have been used. These have confirmed earlier evidence regarding protection by certain substances, and have also shown how the presence of one substance may modify the effects of other substances or environmental factors. Several experiments of this type are still in progress, with differences becoming more important with increasing duration of storage.

Investigations of factors causing death of dried organisms during rehydration have been continued, mainly with a susceptible species of *Vibrio* as test organism. The nature and concentration of the solutes in rehydrating fluids have been found to be of prime importance. The hypothesis that the solutes may control the rate at which water re-enters the dried cells has been supported by experiments with varying rates of addition of water, or aqueous solutions, in the form of mists or small drops.

5. MEAT.

(Division of Food Preservation and Transport.)

(*a*) *Co-operative Investigations*.—The closing stages of this work with the Low Temperature Research Station, Cambridge, were concerned primarily with the changes induced in beef by different programmes of " tenderizing " applied to quarters with and without subsequent freezing. These studies, and others relating to freezing and frozen storage, have also supplied a large volume of data on the nature of the " drip " fluid and its constituents.

(*b*) *Biochemical Studies*.—In a series of studies in parallel with those of the co-operative investigations on tenderizing, the breakdown of nucleotides in the muscle tissue has been examined. This breakdown follows a similar course to the changes in eating quality. While it is yet too early to postulate that these changes are directly related, this possibility is being followed up. Such a relationship would have wide implications, particularly for the separation of influence of freezing, frozen storage, thawing, and post-thawing changes, which is difficult with direct tasting tests. Whether or not a causal relationship is established, the empirical association of tenderizing and nucleotide breakdown during chilled storage supports overseas suggestions of the value of the extent of this breakdown as an objective measure of tenderization. The dynamics of nucleotide breakdown as influenced by temperature and pH have been studied.

Other studies on changes after rigor mortis under chilled storage have examined the nature of the breakdown of glycogen which occurs after rigor without further production of lactic acid, presumably as a result of the action of amylases.

(*c*) *Bacteriological Studies*.—The focal point of bacteriological investigations has been the establishment of the growth curves of typical psychrophilic organisms in air and 10 per cent. carbon dioxide over the temperature range 0-20° C. Such data will provide the background for an investigation of the effect of other levels of carbon dioxide on growth and metabolism at various temperatures.

(*d*) *Freezer Burn*.—During the past twelve months the work on freezer burn on frozen offals has extended our knowledge of the factors which affect the extent of damage when the material is frozen under conditions where evaporation is prevented during freezing. Considerable data have also been accumulated on the influence on dipping in solutions of highly soluble ionic and non-ionic reagents which can penetrate the outer membrane of the offal and modify the extent of freezer burn, presumably by lowering the freezing point of the tissue and the extent of ice crystal formation. The actual structural changes which occur in the tissues as a result of production of freezer burn have been studied by histological techniques, and it is proposed to relate these to microscopic studies of the formation of ice crystals within the frozen tissue.

(*e*) *Ozone Studies*.—Earlier work in which the dynamics of ozone breakdown in the presence of meat was studied at moderate levels of ozone concentration indicated that before this work could be extended to the low levels of ozone concentration, which are likely to be applicable in practice, a solution had to be found to a number of analytical problems peculiar to studies of ozone at concentrations of a few parts per million. This has necessitated a complete study of the analytical techniques and the attempt to establish an absolute method by means of microdifferential density measurement.

6. FISH.

(Division of Food Preservation and Transport.)

(*a*) *Fundamental Investigations*.—Work has continued on some aspects of denaturation of muscle proteins in fish during frozen storage. The influence of the fineness of subdivision of the fish muscle during extraction by salt solutions in different types of disintegrators has been studied.

The degree of extractability of actomyosin in salt solutions and the level of toughness detected by a tasting panel have periodically been determined in one species of fish during frozen storage.

Melanins obtained from prawn tissues have received further study.

(*b*) *Applied Investigations*.—The suitability of pilchards, caught along the east coast of Australia, for the production of fish meal and oil has been assessed by measuring oil and protein in the whole fish at intervals throughout the catching season.

Miscellaneous investigations have been carried out on spoilage in frozen and canned fish products, and processing studies have begun to obtain data on various types of discoloration in canned prawns.

7. EGG INVESTIGATIONS.

(Division of Food Preservation and Transport.)

When fowls have ingested plants from the order Malvale, and specifically from the family Malvaceae, eggs laid by them may show abnormalities in the yolk and a pink discoloration in the white after storage.

A C_{18} fatty acid, malvalic acid, has been isolated from some *Malva* spp. by large-scale reversed-phase chromatography. Feeding malvalic acid in small quantities to fowls has produced the disorders in the eggs laid by them.

Investigation of the structure of malvalic acid has been made using evidence obtained from the infra-red spectra of the acid and of dihydromalvalic acid. It is concluded that malvalic acid contains a *cyclo*propene ring and is thereby related to the C_{19} acid, sterculic acid, which also contains a *cyclo*propene ring.

The feeding of sterculic acid to hens has also produced disorders in the eggs similar to those resulting from malvalic acid feeding.

8. FRESH FRUIT AND VEGETABLE STORAGE.

(Division of Food Preservation and Transport.)

(*a*) *General.*—Much time at both Homebush and Gosford Laboratories was concerned with the improvement of methods for killing fruit fly in harvested fruits. This work, in collaboration with the Entomology Branch of the New South Wales Department of Agriculture, has resulted in the acceptance by the New Zealand Government of the recommendation that oranges from fruit fly areas can be exported to New Zealand if stored at 31° F. for fourteen days instead of 21 days as previously required. This reduction in time, which makes export of fruit from fruit fly areas more practicable, is particularly important because of recent outbreaks in areas not previously affected.

(*b*) *Plant Physiology and Biochemistry.*—A notable development has been the initiation of work on the physiology of sugar cane with the addition of an officer of the Colonial Sugar Refining Company to the Plant Physiology Unit.

Work on the fine structure of the plant cell was continued in collaboration with the Division of Industrial Chemistry. The electron microscope has been used to investigate the structure of both chloroplasts and mitochondria. Papers prepared for publication discuss the structure of plastids and how they are developed in the cell. The work on mitochondria attempted to coordinate biochemical function with structure as shown by the electron microscope.

The study of the effects of inorganic cations and anions on mitochondria has been continued. Salts increase the rate of oxidation of reduced diphosphopyridine nucleotide, probably owing to an effect on the cytochrome system; these results may offer an explanation of how the so-called salt respiration is controlled in the cell. The ionic contents of mitochondria extracted rapidly from cells accumulating ions have also been investigated.

One of the most important investigations has been on the development of peas. Work has shown that the increase in rate of starch synthesis is controlled by a rapid increase in the amount of the synthetic enzyme, starch phosphorylase. A decrease in hexose monophosphate brought about by the increase in starch synthesis is probably responsible for the observed decrease in sucrose by reversing the reactions by which sucrose is formed. These observations may have important bearing on our knowledge of maturation processes in peas.

A collaborative project on pea growth has been carried out with Professor F. W. Went, California Institute of Technology. Pea plants which had flowered were grown under different conditions of day length, temperature, and light intensity in the phytotron, and seeds of different ages from the developing pods were analysed at the Plant Physiology Unit. This experiment is expected to assist in understanding the conditions necessary for the development of better quality in peas.

In collaboration with the Canning Section, pea samples were again taken from commercial crops in Tasmania. Changes in water content and soluble sugar content of the seeds appeared to be closely related to optimal harvest time.

Several investigations involved detailed work on enzymes. Studies on sucrose synthesis by plant enzymes were continued and a sample of enzymically synthesized sucrose was prepared. Uridyl transferase, the enzyme responsible for the formation of uridine diphosphoglucose (precursor of sucrose), was isolated from peas. Peas have also been used as the source of an integrated enzyme system which is responsible for glycolysis but is inhibited by oxygen. Such an inhibition is known as a Pasteur effect and has been localized to one of the enzymes, triosephosphate dehydrogenase.

Phosphate and phosphorylated compounds play a major role in the control of respiration and synthetic processes. During the year it has been possible to follow changes in the phosphorylated compounds in ripening fruits of pears, avocados, and tomatoes. In tomatoes and avocados, the concentration of reactive (energy-rich) phosphate has been shown to follow the drift in the rate of respiration. A paper on the adenosine and uridine phosphates in pea seeds has been completed.

The study of the physiology of development of orange fruits on the tree has been completed and relates physiological changes to morphological and anatomical changes occurring simultaneously.

Both pears and apples have been investigated to obtain more information about development and maturation and, in pears, about the ripening processes. The work on apples from both Orange and Griffith, co-ordinated with work of the Division of Plant Industry in other parts of Australia, attempts a more physiological approach to the judgment of best maturing for harvesting. The work on pears includes changes in morphology, respiration, nitrogen fractions, carbohydrates, and phosphorylated compounds.

(*c*) *Applied Research.* (i) *Gas Storage of Apples.*—The study of varying levels of carbon dioxide and oxygen has been continued, particularly in relation to the development of superficial scald, a serious storage disorder, in the variety of Granny Smith. In previous years increasing the carbon dioxide content of the storage air has increased scald but not in 1956. Last year's conclusion that the best gas storage atmosphere for the variety Granny Smith is likely to be 5 per cent. carbon dioxide and 2 per cent. oxygen still stands, but could be changed by use of an inhibitor of scald. The effects of rates of ventilation and level of fruit volatiles are also being studied. The Jonathan variety responds well to gas storage in 5 per cent. carbon dioxide with 16 per cent. oxygen. Another important variety, Delicious, does not respond well to gas storage and showed increased breakdown.

(ii) *The Control of Superficial Scald on Apples in Storage.*—Work at Homebush has shown that diphenylamine is more effective than wrapping in oiled paper for the control of superficial scald and that it may be applied as a fruit dip, in wraps or in sheets of paper between layers of fruit. Application by spraying the trees before harvest appears possible. Diphenylamine at higher concentrations is also effective in gas storage. Although diphenylamine residues in treated fruit are only 2-3 p.p.m., its human toxicity is under investigation by health authorities and therefore its use cannot yet be recommended. The effect of diphenylamine on other disorders of apples such as soft or deep scald is being investigated.

The quality of oiled paper wraps for apples has been examined in conjunction with the development of standard specifications by the Standards Association of Australia.

At the request of Professor Shutak, University of Rhode Island, experiments have been set up to test the effect of cuticle on scald development. Professor Shutak found that separated cuticle applied to the surface of another apple caused scald.

(iii) *Mould Wastage in Pears.*—Work on control of mould in Winter Cole pears from a large packing house has been continued; some success has been achieved with chemical antiseptics.

(iv) *Packaging Fibre-board Boxes for Fruit.*—Problems associated with the use of these boxes are being investigated by the fibre-board container industry in conjunction with State Departments of Agriculture and C.S.I.R.O. Cooling of apples in fibre-board boxes stacked in 24-box wire-mesh shipping containers was slower than that of apples in standard wooden boxes. This was shown to be a stowage problem since there was little difference between single containers.

(v) *Control of Wastage in Citrus Fruits.*—Citrus packing houses at Monak (near Mildura), Griffith, Arcadia, Gosford, and Mundubbera (Queensland) are now using sodium orthophenylphenate as recommended by the Gosford Laboratory. The effectiveness of the treatment against mould wastage under commercial conditions is proved. Residual protection against mould has been achieved in laboratory trials where the recommended sodium orthophenylphenate " rinsed " treatment is followed by a skin coating of orthophenylphenol with a non-ionic emulsifier, and will now be tested in a commercial packing house. The problem of eliminating rind injuries which occur on fruit in wraps impregnated with sodium orthophenylphenate remains unsolved.

An exploratory trial has indicated that post-harvest dipping of grapefruit in 2,4-dichlorphenoxyacetic acid together with wrapping in diphenyl wraps might be effective in improving storage life and this is being further investigated.

(vi) *Queensland Fruit Fly.*—Artificial infestation of fruits at first resulted in heavy mould losses, but this was brought under control by incorporating a fungicide in the egg suspension medium and by aseptic measures.

Routine fumigations begun in February have been carried out regularly with analyses of the fumigant (ethylene dibromide) in chamber atmospheres and in fumigated fruit. It is hoped that these can be related to fly mortality.

9. CANNING AND FRUIT PRODUCTS.

(Division of Food Preservation and Transport.)

(*a*) *Vegetable Canning.*—Experimental studies of those factors which contribute to quality in canned green peas were continued in New South Wales and Tasmania. It has been shown that a crop may be harvested precisely at the point when most of the yield is in the first-quality range, and this portion may be separated from the second-quality material by the use of a size grader. This arbitrary separation is not always adequate, because of the extraordinary variability in maturity of peas, within any one size grade, even though in general maturity and size they are very closely related. Some means of extracting overmature peas from any given size grade is therefore required. Consequently an investigation was made of the commercial process of maturity separation by gravity, which depends upon the principle that peas float or sink in a solution of common salt depending upon their respective densities. Prior to immersion in salt brine it is necessary to expel gases within the pea by hot water treatment known as blanching. A study of blanching technique was therefore involved in the investigation. The results of this work suggest that the present commercial blanching procedure may be shortened from the conventional three-minute period to about 40 seconds, the reduced time effecting a saving in the loss of soluble material from the pea and lessening the amount of destruction of green pigment. The gravity separation procedure was tested on a commercial scale, and preliminary results indicate that under carefully controlled conditions an effective separation of peas on a maturity basis may be made at feed rates up to 8,000 lb. per hour. Further work is necessary to confirm these findings.

A pea grader operating on the moving belt principle was designed and constructed within the Division. It possesses greater dimensional accuracy than the conventional perforated grader, and permits blanched peas to be handled without damage. This grader was essential to the blanching and gravity separation investigation.

Trials of tomato varieties for suitability for canning and pulping were continued in Richmond, New South Wales, during the 1957 season when excellent weather conditions prevailed throughout the growth and harvesting periods. Four varieties—Urbana, Grosse Lisse, Red Top, and Tatinter—were tested in a randomized block design and Urbana was outstanding in yield. Data on chemical composition and quality factors have yet to be assessed.

(*b*) *Fruit Canning.*—Maturation studies on J. H. Hale freestone peaches at the Bathurst Experiment Farm of the New South Wales Department of Agriculture were continued during a second season. Conditions of high temperature and low rainfall prevailed in contrast to the low temperatures and high rainfall of the previous season. Growth increment curves were constructed from weekly measurements of the cheek diameter of 600 fruits on twelve trees, and again showed a well-defined peak during late developemnt. The chemical composition, ripening characteristics, and canning quality of peaches harvested at several stages of maturity have been examined, and the information will be used to define the optimum picking maturity for freestone peaches for canning.

Investigations on concentrated orange juice have shown that the canned product pasteurized in a spin-cooker is equivalent to the frozen product in initial quality, but deteriorates in colour and flavour during storage at ordinary temperatures. The possibility of extending the storage life by the addition of sulphur dioxide as an inhibitor of browning reactions is being explored.

With the advent of the new Food Processing Annexe at the Tasmanian Regional Laboratory, investigations on the canning of berry fruits were intensified. Further work on the canning of berries in syrup containing pectin is in progress; the new investigations are designed to give data on the storage behaviour and consumer acceptability of these packs. The effect of syrup concentration and of thermal process on the quality of canned berries is also under investigation.

(*c*) *Chemistry of Processed Foods.*—It is now possible to postulate a reasonably complete molecular structure for limonin, the bitter principle of oranges. The isolation of 1,2,5-trimethyl-naphthalene and the identification of a furan ring indicate that limonin is probably closely related to two other bitter principles, columbin and marrubiin, for which structures have recently been proposed. Assuming a carbocyclic system similar to columbin and marrubiin, the relative positions of the ketone, furan, two lactone, and two ether groups in limonin can be established from its known behaviour in oxidative, reductive hydrolytic, and hydrogenation reactions.

The investigation of the dark red pigments of blackcurrants has revealed a more complex system than was at first suspected, consisting of at least four anthocyanin pigments. By passing pigment extracts through cellulose columns it is possible to obtain a good separation of seven components, comprising two cyanidin glycosides, two delphinidin glycosides, and two parent anthocyanidins, and an artefact. Hydrolysis of the glycosides yields glucose as the only sugar. Complete identification of the pigments is being sought by comparative paper chromatography with known anthocyanins.

With the aid of chromatographic and spectrophotometric techniques, changes in chlorophyll content in canning peas during maturation are being followed, and it appears likely that these changes will correlate well with other physiological changes observed in maturing peas. Pigment changes in green vegetables during various stages of processing are also being studied in an attempt to devise procedures which will give improved retention of natural colour.

(*d*) *Container Investigations.*—Studies designed to determine the effect of different amounts of initial oxygen in the headspace of highly corrosive canned products were continued by means of test packs of blackcurrants in syrup. Results from this test confirm those of two previous test packs of acidified beetroot, when it was found that high levels of initial oxygen induce an accelerated rate of hydrogen production during storage. Losses due to hydrogen swelling may therefore be reduced by ensuring that cans are closed with high potential vacua before processing.

Experimental work has been completed on twelve test packs made to compare the performance of a relatively light coating of electrodeposited tin (1 lb.) on tin plate with that of standard hot-dipped tin plate (1.25 lb.). This work is being conducted in co-operation with the Commonwealth Canmakers' Association. Three additional test packs were made to study variation in performance of five lots of plate of American and Japanese origin. Early results indicate that variation between batches of the American plate is small. The Japanese electrolytic tin plate showed poor corrosion resistance.

10. FROZEN FRUITS AND VEGETABLES.

(Division of Food Preservation and Transport.)

Investigations on the freezing of fruits and vegetables are conducted jointly by the New South Wales Department of Agriculture and the Division of Food Preservation and Transport.

(*a*) *Freestone Peaches.*—Further progress has been made in the evaluation of varieties grown in New South Wales. Several varieties have now given very satisfactory results in experiments extending over at least three years. Measurements of browning rate, tannin content, polyphenolase activity, and loss of added ascorbic acid during storage have been related to subjective observations on the colour of the finished product.

(*b*) *Apricots.*—A small trial on the methods of preparation of frozen apricots for later processing into jam or conserve is almost complete.

(*c*) *Berry Fruits.*—Studies on methods of preparation and effects of storage of frozen raspberries and strawberries are proceeding. This work has been undertaken on a co-operative basis with the Organization's Tasmanian Regional Laboratory. The main emphasis in recent experiments has been on the effect of storage at temperatures above O° F. on the quality and life of the product.

(*d*) *Peas.*—In a study of the freezing quality of successive pickings of the varieties " 99L ", Cooper's No. 75, and Greenfeast, some differences between varieties were observed. At an early stage of maturity, samples of the variety Greenfeast were slightly inferior to those of " 99L " and Cooper's No. 75, while at a more advanced stage Greenfeast was slightly superior to the other two varieties.

Analytical work on a large number of samples of peas processed at different stages of maturity have made it possible to apply a convenient laboratory procedure for testing the maturity of peas after freezing.

A small trial on methods of precooling and holding peas before processing is in progress.

Blanching experiments in which the main object was the reduction of skin toughness have been completed. The results of this work were indefinite and further investigations will be made.

(*e*) *Beans.*—Frozen samples of five recently introduced varieties of stringless beans grown in a replicated trial at Yanco Experiment Farm were prepared. After four months' storage, the quality of all lots was satisfactory, with only small differences between varieties. Seminole and Processor showed particular promise.

A problem of discolouration in the commercial freezing of beans was investigated and found to be associated with metallic contamination.

11. DEHYDRATED FOODS.

(Division of Food Preservation and Transport.)

(*a*) *Vegetables.*—Work on maturing pea crops at Hawkesbury Agricultural College corroborated last year's result that peas for dehydration should be harvested earlier than peas for canning. The range of maturometer readings producing satisfactory dehydrated peas was more closely defined from this season's results.

An experiment begun last year to test the deterioration of dehydrated peas stored in cans containing different oxygen tensions has shown no large differences with levels of 0, 1, 2, 4, and 20 per cent. oxygen.

Some peas dry slowly and reconstitute poorly owing to the skin being a considerable barrier to moisture transfer. Processing treatments designed to break the skin have so far not been successful.

A study of the dehydration of sweet corn showed that the optimum maturity at picking was in the range of 70-73 per cent. moisture. A bulk sample was prepared for supply to Army authorities for acceptability testing.

Quality tests were done on varieties of potatoes bred by the New South Wales Department of Agriculture. These new types were generally of a high-quality standard.

(*b*) *Fruit.*—Work on the uptake and retention of sulphur dioxide by cut fruits before drying was advanced during the year. Data were obtained on losses during sun-drying and methods to improve retention. Data on William pears showed them to react similarly to Winter Coles.

Data on shrinkage and weight differences between peeled and unpeeled peaches were obtained so that the Australian Dried Fruits Association could apply premiums for the supply of peeled dried fruits.

(*c*) *Dehydrated Mutton.*—Investigations concerned with the effects of flavouring additives both on flavour and on shelf life have been completed. Two attempts were made to limit deterioration during storage by controlling " the browning reaction ". The first study, in which sulphur dioxide was used as the protecting agent, has been completed. The second one, involving the use of in-can desiccants to lower the moisture content, is still in progress. Protective effects have been noted in both cases.

A collaborative experiment with the British Ministry of Agriculture, Fisheries, and Food has been completed. Raw materials, processing methods, and methods of examination were compared. Air-dried mince compared favourably with vacuum-dried mince (vacuum pressure plate dryer).

To aid in the design of commercial dryers, experiments have been commenced to collect physical data on drying rates of dehydrated mutton mince.

(*d*) *Dehydrated Beef.*—Storage studies on dehydrated beef mince have been continued.

The joint experiment with the New Zealand Department of Scientific and Industrial Research on dehydrated beef chunks is still in progress. Beef chunks were vacuum dried in New Zealand and brought to Australia for storage studies.

12. DAIRY PRODUCTS.

(Dairy Research Section.)

(*a*) *Microstructure of Dairy Products.*—Fluorescence microscopy has been applied to the study of casein in milk, to the rennet clotting of milk, to fused cheese curd, and to finished cheese. Aggregation and network formation have been observed in clotting, and enmeshed fat globules have been clearly shown by the use of differential fluorochromes. There is a tendency for the particles in the floc to form short strings when acidified. In the curd-fusing process, the spheroidal casein particles tend to form long fibrils, and the extent to which the curd exhibits a fibrous structure on the macro scale is closely related to fibril formation on the macro scale. The grain boundary layers of curd particles have been studied in finished cheese.

Microscopic study of mechanically fused curd is providing insight into the " cheddaring " process.

(*b*) *Flavour Chemistry.*—A gas chromatography unit has been built and is being used for the detection and separation of very small quantities of volatile flavour compounds. The first problem to which the technique was applied was that of fishy flavour in butterfat.

Experimental evidence from other parts of the world suggests that oxidative flavour defects in milk may be initiated in the phospholipin fraction. Hitherto, it has been difficult to separate pure phospholipin from fat. A chromatographic technique has been successfully applied and the phospholipin has, in turn, been separated by this means into two well-defined bands. The phospholipin fractions are now being used in oxidation studies.

Regular monthly observations have established that Melbourne milk is more resistant to copper-induced oxidized flavour in autumn and early winter than it is in spring and early summer. The resistance of milk to light-induced oxidized flavour has not shown this seasonal variation.

(*c*) *Cheese Studies.*—A prototype cheese-curd fusion or " cheddaring " machine was constructed by the Engineering Section of C.S.I.R.O. It has worked effectively, giving an excellent curd matt. Cheese made in the machine showed at six months all the characteristics of a good-quality Cheddar cheese of that age. The texture of curd cheddared in the machine is rather more fibrous, and tends to retain slightly more moisture than curd cheddared in the traditional manner.

With successful mechanization of cheddaring it becomes possible to mechanize the entire cheese-making process, and pilot-scale machinery to slice, salt, and hoop cheese curd is now under construction.

Cheese milk at times inhibits the growth of the lactic acid bacteria which are essential to the cheese-making process, and this difficulty has been troublesome in many cheese factories this year. A study was made of the sensitivity of various starter strains to lactenin, penicillin, and nisin, and day-to-day variation in the inhibitory effect of milk is now being investigated. A phage-resistant medium for growing cheese starter organisms was tested and evaluated.

(*d*) *Vitamin Fortification.*—A metering pump has been devised for continuously adding in correct proportion a vitamin preparation to milk concentrate before drying.

A nine-months storage test, at 30° C. and at room temperature, on the stability of vitamin A in sweetened condensed milk has been completed. The results show excellent stability when an oil solution of vitamin A acetate is used.

In a series of tests under commercial conditions, neither homogenization nor HTST pasteurization had any effect on the vitamin A content of whole milk.

(*e*) *Modified Non-fat Milk Products.*—Commercial tests of modified milk powder for cake-making have reached an advanced stage, and batches of up to 1 ton of cake have been prepared. A variant of the powder, in which skim milk concentrate of 40 instead of 25 per cent. solids is used, has been made. A higher bulk density and lower production costs should result.

The reactions of milk concentrate with lime and with calcium sequestering agents have been further studied. It was found that caseinate solutions did not exhibit typical changes in viscosity unless the casein was in micellar form. The removal of calcium with sequestering agents is thought to destabilize the casein globules in milk, with the result that molecules are randomly freed, which increases viscosity. At a later stage they orientate, which causes a decrease in viscosity.

It has been predicted theoretically, and shown experimentally, that the process of " instantizing " milk powders promotes the Maillard protein-sugar reaction.

(*f*) *Butter Storage Temperature.*—Twelve hundred boxes from 200 churnings of butter, made at ten factories throughout Australia, were held at storage temperatures of + 12, 0, and − 12° F., to see whether any advantage would accrue from the lowering of the storage temperature used in practice (+ 12° F.), which is considerably higher than that used for long storage of butter in the United States of America or in European countries. After three months, the butters were graded, and no significant difference in quality was noted. Further observations will be made after six months.

13. DRIED VINE FRUITS.

(Commonwealth Research Station, Merbein.)

The Station continues to assess the performance of commercial dipping oils used in the drying of sultanas. This is done by means of field trials and laboratory experiments. All commercial oils available for 1957 showed satisfactory behaviour with respect to drying rate, stability of dipping emulsion, and quality of dried fruit.

The following modified procedure has been used for testing new dipping oil formulations. By means of field trials sufficient fruit is treated with the new dip until it has been used for approximately half its life, and the quality of the fruit is compared with that produced by one of the well-tried commercial dips. A laboratory determination of the relative drying rates of dip samples taken just prior to and immediately after dipping indicates whether oil has been stripped from the dip during use.

A tunnel dehydrator has been installed to investigate the advantages and economy of this method for drying fruit, especially during adverse weather conditions.

Facilities were made available for an officer of the Division of Industrial Chemistry to test the performance of solar energy absorbers for drying fruit.

Various organic solvents were tested for their suitability for estimating the amount of cuticle on a grape. A definite amount of material was extracted with non-polar solvents, and of these chloroform and carbon tetrachloride were the most efficient. Polar solvents were most unsuitable because they dissolved varying amounts of sugars. The average amount of cuticle on the sultana varies very slightly during the drying season and with soil type and locality for the limited number of samples investigated. Cold and sulphite dipping does not alter the average amount of cuticle on the grape, and it is concluded that the faster rates of drying achieved with these dips is brought about by changes in the cuticle structure. A small amount of cuticle is removed from gordos by the hot alkali dips, but this reduction is not sufficient to account for the increased drying rate produced by these dips. It is concluded that the hot alkali dips also change the structure of the cuticle.

The permeability of the cuticle to water was calculated for individual untreated grapes from the drying rate data obtained with well-defined conditions of temperature, humidity, and air flow. The cuticle was removed from each grape by a micro-extraction with carbon tetrachloride, and the amount determined by weighing with a micro-balance. It was found that there were large variations in the permeability and the thickness of the cuticle for individual grapes. The permeability increases with temperature, but it does not vary according to the expected exponential function of temperature.

Treatment of the grapes with ethyl oleate increases the permeability to water, and like untreated grapes the permeability has a positive temperature coefficient. It is found, however, that the permeability of an ethyl oleate treated grape remains constant in spite of a rise in temperature which occurs during drying. The factor which is tending to reduce the permeability during drying is probably the slow evaporation of ethyl oleate from the grape.

An apparatus has been designed and constructed for determining accurately the permeability of grape skins free from the large temperature variations usually encountered during the drying of grapes.

XIV. FOREST PRODUCTS.

1. General.

The Organization's Division of Forest Products, with its laboratory in Melbourne, was formed to carry out investigations on Australian forest products and to give direct assistance to all concerned in the utilization of forest resources.

Australia is not a heavily forested country, although a wide range of eucalypts and other species of timber is available. Full and proper use of existing timber resources is therefore essential, and this can be achieved only with the aid of fundamental data on the properties, potentialities, and correct methods of treatment of our timbers.

The Division's research is directed toward more effective use of these resources, by reducing waste in forest, mill, and factory; by reducing losses from decay and insect attack; and by improving the quality of timber produced in the growing forest by the study of the relationship between silvicultural treatment and timber products. The work of the Division is reported in this chapter. Some work on timber pests is undertaken by the Division of Entomology (*see* Chapter IX., Section 13).

Division of Forest Products.—The past year has been a difficult one for the wood-using industries. This has resulted in further demands upon the Division, and enquiries increased by 2,000 to 12,000. Visitors to the Division also increased by about 20 per cent. to 2,400. Some of the increases have been due to renewed activity in plywood research.

The first year's work under the co-operative programme with the plywood industry was a difficult one because lack of security of tenure prevented building up the necessary technical staff. By drawing on all Sections good progress was made, and the Division was able to demonstrate the value of research to the industry. The Australian Plywood Board has now agreed to contribute £8,000 per annum for the next three years. Pole investigations were continued and a further £9,000 was received in cash contributions, together with material to the value of £2,000. Much of the testing work has been completed. General contributions from industry were similar to last year and totalled about £3,000.

The timber mechanics investigations at the Engineering School, University of Western Australia, have been continued.

The Chief of the Division, Mr. Stanley A. Clarke, attended the F.A.O. World Eucalyptus Conference in Rome, in October, 1956, and led the section on Utilization. Mr. J. D. Boyd, Officer-in-Charge of the Timber Mechanics Section, attended this conference also and presented his paper which was one of the six major papers on utilization prepared by officers of the Division. Dr. A. B. Wardrop attended the Third Lignin Round Table at the Institute of Paper Chemistry, Appleton, U.S.A. Messrs. C. M. McK. Stewart, A. J. Watson, and A. W. McKenzie attended the Australian Pulp and Paper Industry Technical Association Annual Conference held at Rotorua in New Zealand in March, 1957.

Visitors to the Division during the year included scientists from the United Kingdom, New Zealand, Rumania, Indonesia, Burma, Egypt, India, North Borneo, Formosa, Malaya, South Korea, the Philippines, and Hawaii.

In addition to help in training research officers from countries of the region, the Division played an important part in the activities of the Committee on Forest Products Research of the F.A.O. Asia-Pacific Forestry Commission. It reviewed published data on the mechanical properties ot teak, and made recommendations regarding future work. It undertook a study of the factors affecting durability of natural and plantation-grown teak, and progress has been reported to the 2nd Session of the Teak Sub-Commission. Officers of the Division participated in the work of the nomenclature and grading sub-committees, and notes were prepared and circulated on the planning and operation of research programmes.

In association with the Forestry Commission, and the Associated Country Sawmillers of New South Wales, lectures and demonstrations on grading were given at Canberra and Wollongong. Seasoning classes were held at Coff's Harbour, at the request of the Associated Country Sawmillers of New South Wales, and in association with the Division of Wood Technology; in Brisbane, at the joint request of the Queensland Sawmillers' Association and the Queensland Timber Stabilization Board; and in Tasmania in co-operation with Tasmanian Timber Association. Demonstrations of new peeling techniques were given in the Division and at plywood mills in Cairns, Brisbane, Coff's Harbour, and Sydney. Demonstrations of fence post preservation with the portable low-pressure unit were given in South Australia and New South Wales. An exhibit panel featuring laminated and built-up structural members was prepared for the Building Industries Fair late in 1956. Portable exhibit boxes were prepared featuring circular saws and sawing, wood-destroying insects and decay of timber, wood identification, and timber utilization. Courses of lectures were given to students of architecture, forestry, and industrial management.

The *Forest Products Newsletter*, reporting technical progress to industry, continued to be issued at monthly intervals, and a new periodical, *Plywood Technical Notes*, had its first issue during the year. It is distributed to the plywood industry.

The help and co-operation of the paper companies, the Australian Plywood Board, the pole-using authorities, the Commonwealth Forestry and Timber Bureau, the State Forest Services, the New Guinea Department of Forests, and of all branches of the timber and allied industries are gratefully acknowledged.

2. Wood and Fibre Structure.

(Division of Forest Products.)

(*a*) *Anatomical Investigations*.—(i) *Wood*.—The investigations of the anatomy of timbers of the south-west Pacific area have continued. Results for the Flacourtiaceae and Cunoniaceae have been published; those for the Burseraceae are being analysed prior to publication. Work is proceeding on the Sapindaceae, Monimaceae, and Combretaceae. A New Guinea species previously placed botanically in *Nouhuysia* has been examined to suggest taxonomic affinities. The genus certainly does not fit in Guttiferae in which it has been placed, but does have, from the viewpoint of wood anatomy, relationships with the Aquifoliaceae. Further woody material of *Sphenostemon*, to which genus some botanists have transferred the New Guinea species, is being sought from New Caledonia.

(ii) *Lignotubers*.—These are formed as swellings at the base of the seedlings of certain eucalypt species and reach their greatest development in the mallees. A study of their structure is proceeding. They are of importance in providing quick regeneration after fire or other damage. The work has shown that they not only arise in the cotyledonary nodes but also in the three or four lowest stem nodes which are similar in structure to the cotyledonary nodes but differ from the upper stem nodes in the number and distribution of the axillary buds. The change from one type of node to the other is now being investigated.

(iii) *In Relation to the Penetration of Liquids into Vood.*—Features of softwoods which militate against the enetration of certain preservatives are being investigated. t has been established that penetration may be facilitated y the removal of lipoid components, and further that the tate of these components may be influenced by the extent f drying before penetration. It has been found that hey form part of a membrane, and line the fibre cavities nd the pits between the fibres. This membrane has been isolated and its structure examined in the electron microscope.

(*b*) *Identification and Identification Methods.*—Over 670 identifications from various sources have been carried out during the year. The revised card sorting key for New Guinea timbers based on macroscipic features is nearly complete. Numerous paper samples were examined to determine fibre furnish for comparison with that of paper from forged currency notes.

(*c*) *Reaction Wood.* (i) *Compression Wood.*—It has been considered of some importance to correlate degree of lean with severity of compression wood formation in *Pinus radiata.* Material from some 48 trees of this species, with varying degrees of lean up to 11°, taken from one plantation in Victoria, have been examined, and although compression wood was formed on the lower side in each case, its severity was not such as to militate against the use of the timber for normal purposes.

(ii) *Tension Wood.*—In previous work it has been established that the defects which this form of reaction wood produces in sawn timber are derived from its submicroscopic organization and the lack of lignification in the cell walls. As tension wood develops asymmetrically in the stem a study has been made of the distribution of peroxidase and possible lignin precursors in areas where it is being formed. It has been found that the tension wood is characterized by a high persistent peroxidase activity, and further, in the cambial zone from which the tension wood arises, there appears to be a deficit of phenolic substances which may include lignin precursors. If this is so, then the lack of lignification is associated with a deficiency of lignin precursors and not a deficiency of peroxidase.

(*d*) *Cell Wall Structure.*—The structure of the outer layer is considered to be of some importance in the reaction of isolated fibres to beating, as in paper manufacture, and in governing certain aspects of shrinkage in wood. As a result of optical and electron microscopy a clearer picture of its structure is beginning to emerge. It has been shown to consist of two grid systems, each with microfibril bundles intersecting nearly at right angles. There is the fine grid adjacent to the primary wall on which is deposited the coarser grid of similar orientation, the microfibril bundles of the former being 600 Å wide and those of the latter 2000 Å. The innermost system of microfibril bundles of the coarse grid (i.e. nearest the lumen) may be elaborated into a complete lamella. The lattice or grid structure observed is related to the separation of this layer into lamellae during beating; it also forms a basis of explanation of certain aspects of the anisotropy of shrinkage of wood during drying.

(*e*) *Assessment of Wood Quality.*—The development of techniques has progressed, with the use of specimens from trees being selected for parent-progeny investigations by the Queensland Department of Forestry. Radial strips of wood from pith to bark carefully cut out of living trees have been used. These are sufficiently large to determine cell length, micellar angle, basic density, and longitudinal shrinkage in the early and late wood of successive growth rings, and this is being done with specimens of *Pinus elliottii.* The object of this work is to obtain as much information as possible on wood quality from pith to bark, so that those trees most suitable from this aspect can be selected as parents.

(*f*) *Bark and Wood Extractives.*—The tannin contents of various samples of bark collected during a survey of the mangrove swamps in Papua have been determined. Results confirmed those of an earlier survey which showed that the bark of certain species is suitable for commercial exploitation. Further assistance was given to the firm producing the mangrove extract, and basic information to permit improvement and control of the process was determined. An active part has been taken in the co-operative work within the Division relating to the development of a suitable adhesive from the extract. The polyphenols in the cambial zones of eucalypts are being investigated to determine whether they play any part in the formation of heartwood extractives.

3. WOOD CHEMISTRY.

(Division of Forest Products.)

(*a*) *Lignin and Related Compounds.*—Analysis of methanol lignin from *Eucalyptus regnans* has shown that, apart from its high methoxyl content, its elementary composition is similar to that which has been deduced by various methods for the protolignin of spruce. Syringyl alcohol has been synthesized, and its absorption spectrum determined and compared with that of methanol lignin. The two substances have coinciding maxima and are in agreement with the conception that most of the phenolic groups of the lignin are syringyl alcohol groups. A lignin-like material separated by counter-current distribution during the purification of methanol lignin was found to give the usual lignin oxidation products, but the ultraviolet and infra-red absorption bands were poorly defined and an extra infra-red band was present. The material is therefore considered to be a degraded lignin.

(*b*) *Chemistry of Reaction Wood.*—Tension wood lignin from an immature eucalypt showed the spectral characteristics of lignin from normal mature wood. The lignin from wood opposite tension wood had a lower ratio of syringyl to guaiacyl nuclei than normal. Compression wood lignin from *Pinus radiata* had a lower methoxyl content than normal, and the presence of methoxyl free nuclei was indicated by the identification of *p*-hydroxy benzaldehyde in the oxidation products. The compression wood of *Pinus radiata* and tension wood of *Eucalyptus goniocalyx* both contain much greater quantities of galactose than the normal woods.

(*c*) *Mechanism of Delignification.*—The investigation of alkali delignification of *E. regnans* wood has been extended to include the action of sodium hydrosulphide. This reagent converts lignin to a thiolignin which is more readily soluble in sodium hydroxide than the original material. The pH of the sodium hydrosulphide solution controls the amount of lignin dissolved during cooking, and also the sulphur content of the lignin remaining undissolved. The former increased with pH while the latter decreased. At fixed pH the concentration of the sodium hydrosulphide has a small but definite effect on the reaction which is much more pronounced at pH 9.0, or lower, than at pH 10.1. Pentosan removal is also increased by raising the pH, but is almost independent of the concentration of sodium hydrosulphide at fixed pH.

(*d*) *The Process of Fibre Separation.*—This appears to be controlled by the hydrolysis of covalent bonds rather than by physico-chemical processes such as swelling. Alkalis are much more effective than acids in catalysing this hydrolysis. Acid hydrolysis, and the resultant increase in ease of mechanical separation of fibres induced thereby, appears to occur within living trees; as would be expected, the greater the age of the wood, the easier it is to defibre.

(*e*) *Pulping of New Guinea Timbers.*—Bleaching studies have been made on sulphate pulps prepared from *Araucaria klinkii.* Good-quality bleached pulps were obtained under conditions similar to those used in the commercial bleaching of the conventional types of sulphate softwood pulps.

(*f*) *Pulping of Compression Wood.*—Both sulphate and sulphite pulps prepared from compression wood of *Pinus radiata* were inferior in yield and strength properties to those made from normal wood from the same species. However, the compression wood pulped satisfactorily under the same conditions as required for normal wood when the sulphate process was used, and the reduction in strength properties, due to the compression wood pulp, was not considered too serious, even when 50 : 50 blends of such pulp with commercial pulp of the same species were tested. On the other hand, the sulphite process was unsuitable, mainly because of the association of " acid susceptible " wood with the compression wood. In such wood numerous minute compression failures are present and these give rise to " broken fibres " on acid pulping.

(*g*) *Papermaking Properties of Thick-walled Fibres.*—Strength development in thick-walled fibres of eucalypt origin may be enhanced by the inclusion of a swelling agent in the beater stock. The high concentration necessary and the corrosive action of the reagent, e.g. monoethanolamine, would prohibit such treatment at the practical level. Various types of laboratory beater have failed to develop strength of practical interest in sulphate pulp prepared from *Eucalyptus hemiphloia* (basic density: 58 lb./cu. ft.). With the exception of the Lampen mill, these various beaters tend to break down the pulp and so to affect its drainage characteristics adversely. Consideration is therefore being given to new designs of beaters. As no information is currently available, a survey of chemical characteristics of high-density eucalypt woods in relation to the properties of their pulps has been initiated.

(*h*) *Mechanism of Beating.*—Further attention has been paid to methods of improving the efficiency of the beating process. The role of swelling has been evaluated by treatments which alter the degree of swelling of the fibre to values both below and above that obtainable in water. By increasing the swelling, improvements in the paper strength reached after a given degree of beating can be obtained, but a high degree of swelling does not lead to a corresponding increase in beating rate. The principle of " fractional " beating, referred to in previous reports, warrants further study. A study of the possibility of using specific drainage resistance as an index of beating has been made.

(*i*) *Interfibre Bonding and Rheological Behaviour of Paper.*—On the basis of various experimental data, including the influence of fibre chemistry, fibre dimensions, and external factors of the rheological behaviour of paper, it has been concluded that the molecular interpretation of the stress-strain curve put forward by Nissan may be adequate for a hydrogen-bonded continuum such as cellophane, but that it is inadequate for a material such as paper, in which perhaps 1 in 10,000 of the total hydroxyl groups are normally involved in interfibre hydrogen bonding. Ample evidence has been accumulated, however, that hydrogen bonding provides the main basis of paper strength. An analysis has been made of the deformation of papers of various structural patterns over extended periods at constant load (creep).

(*j*) *Hydrodynamics of Pulp-water Systems.*—A study of factors such as pulp concentration and degree of beating, which influence the drainage rate on the paper machine, has been made with a stationary wire. Cinephotography has been used to record accurate volume-time data in a standard handsheet machine, and progress has been made in the design of an electrical instrument for determining similar data from which specific drainage resistances can be computed.

(*k*) *Application of Infra-red Spectroscopy to Cellulose Problems.*—Infra-red techniques have proved valuable in the study of cellulose crystallinity, the differences between various forms, and the way in which cellulose reacts with other materials and with itself. Modifications to both the hydrogen bond systems and the covalent bond structure under conditions favouring esterification, degradations, and other changes have been followed. Techniques which have been particularly useful include hydrogen-deuterium exchange and the pressed alkali halide disk method for studying finely dispersed solids. Several other wood constitutents, wood itself, and ultra-thin papers have also been examined by infra-red methods.

4. TIMBER PHYSICS.

(Division of Forest Products.)

(*a*) *Sorption Studies.*—A detailed investigation of the sorption isotherms and heats of wetting of the constituents of a single representative sample of *Eucalyptus regnans* has been completed, except for the non-cellulosic polysaccharide fractions. The adsorption isotherms for whole wood, holocellulose, cellulosic polysaccharides, and Klason and methanol lignins were all of the same sigmoid form, but the moisture content of the methanol lignin was only about half as great as that of the Klason lignin, which did not differ markedly from the other constitutents. The sorption hysteresis was less for the cellulosic constitutents than for the whole wood, but it was much greater for the lignin samples.

The heats evolved on wetting the dry materials varied in approximately the same manner as their sorptive capacities, but the variation in the differential heat of sorption with relative vapour pressure for methanol lignin was markedly different from that for the wood and the cellulosic constitutents, whereas the Klason lignin differed only slightly from the other materials.

The sorption isotherm for klinki pine wood at —5° C. has been determined. The approach to equilibrium is very much slower at this temperature, and the determination of the isotherm therefore takes a considerable time. As at higher temperatures, a decrease in temperature is accompanied by an increase in equilibrium moisture content at a given relative vapour pressure.

Adsorption isotherms at 40° C. have been determined for klinki pine wood in different states of subdivision, including longitudinal sections both 1 mm. and 20 microns thick. The isotherms did not differ appreciably at relative vapour pressures below 0.80, and the rates of sorption for the different types of specimens were practically identical. Sorption appears to be a two-stage process, the rate of sorption in each stage decreasing with an increase in relative vapour pressure. The effect of the temperature rise of the specimen during sorption on the rate of sorption is being studied.

The freeze drying of small samples of klinki pine has been studied and it is has been found that, under certain conditions, the drying rate may be quantitatively related to the capillary radius, close agreement being found between values of the radius determined from freeze drying experiments and by other methods.

(*b*) *Shrinkage and Density Measurements.*—The shrinkage and density of wood from immature trees of ten eucalypt species have been measured. When compared with mature material of the same species, the immature wood was found to shrink more, both tangentially and radially before reconditioning, and tangentially after reconditioning. The amount of collapse, as indicated by the recovery on reconditioning, and the intersection points were also greater for the immature material. Basic density, on the other hand, was slightly less for immature material. Measurements have also been completed on material from 43 miscellaneous species.

(*c*) *Creep and Related Phenomena.*—Tests on beams of blackbutt and mountain ash under continued loading have shown that the two species behave in a very similar manner, both qualitatively and quantitatively, when green, when dry, and when allowed to dry out whilst under load. Tests on these species confirmed that the creep and creep rate are greater when the timber is allowed to dry out under load than for either green or dry material. This was also found to be the case for radiata pine. For all these species the shortening of the compression face was found to be greater than the elongation of the tension face. The proportional difference was greater for material drying during test.

The time to failure under continued loading has been studied in tension and bending. It has been found extremely difficult to obtain consistent results in tension because of slight cross grain and other defects. However, consistent results have been obtained in bending. The time to failure in bending increases from 4 min. at 90 per cent. of ultimate load to 20 hr. for 80 per cent. and many weeks at 70 per cent. Further, the percentage variability in the time to failure appears to decrease rapidly with decreasing stress.

(*d*) *Electrical Moisture Meters.*—Species correction figures for immature messmate stringybark have been determined over the range 8–40 per cent. moisture content.

An investigation into methods of determining the moisture content of both treated and untreated veneer has been carried out using an electrical-resistance moisture meter with needle electrodes and with standard veneer electrodes, a capacity-type meter designed to give a small field penetration, and a surface hygrometer. A complete analysis of the results has not yet been made, but it seems that for industrial use, moisture meters with needle electrodes can be used on veneer without species or thickness correction even in the presence of preservatives.

5. TIMBER MECHANICS.

(Division of Forest Products.)

(*a*) *Studies of Properties and Testing Methods.*—Creep compression tests were made at temperatures from 40 to 190° F. to check the possibility of shortening the time scale. A mathematical study, based on experimental stress-strain curves, was made of form factors; the calculations gave results approaching the experimental values, but the assumptions used limited the value of the approach.

(*b*) *Species Testing.*—Green tests were made on nine Victorian trees, including six of Douglas fir, and also on five New South Wales trees of crow's ash. Other tests were made on the dry material from 89 Queensland species.

A paper has been prepared on the properties of klinki pine and a bulletin published on the properties of 100 Australian and New Guinea species. A paper has been prepared, in collaboration with the Division of Mathematical Statistics, on the sampling of timber for mechanical tests.

(*c*) *Silvicultural Tests.*—Compression and bending tests on radiata pine of average growth from Mundaring, Western Australia, supported the relationship established earlier between strength and age, and also the dependence of strength primarily on percentage of late wood. This held also for extremely suppressed radiata from the same area showing increased density. A statistical analysis of data available on radiata pine showed that growth rate (rings per inch) is not related to strength in a practically useful manner.

(*d*) *Timber Construction.* (i) *Structural Design.*—Structural designs investigated included trusses, rigid frames, stressed skin constructions, and I-beams, in addition to a number of unusual built-up columns and floor systems; some elements were proof tested. The Division's publication on timber design has been rewritten and now includes new material, particularly on plywood and glued laminated construction.

(ii) *Connectors.*—Ring connector specimens were dismantled after periods up to nine years under load and tested to failure with quickly applied load.

Some lateral loading tests made on pressed steel connectors for building scantling, using nails one gauge smaller and ¼ inch shorter than recommended by the designers, suggested that such variations were not critical in hardwoods.

(iii) *Nails.*—Lateral loading tests have been made on joints in radiata pine, yellow stringybark, and jarrah. Measurements of withdrawal resistance of plain and cement-coated nails in mountain ash, karri, and radiata have been completed. For both building and case use plain nails have a greater holding power in hardwoods than coated nails when driven into green timber and withdrawn after drying. Testing has commenced on the holding power of helical and annular grooved nails in radiata pine.

(iv) *Columns.*—Nineteen columns were erected during the year. Of the total of 355 now erected, 271 have failed. Messmate stringybark, yellow stringybark, and Douglas fir columns loaded to 70 per cent. of the estimated short-duration failure load broke within a few weeks. This period was extended to some months under a 60 per cent. load, with the Douglas fir lasting longer than the eucalypt columns. Under 50 per cent. load, only one of 21 mountain ash columns remains after five years, but of the six yellow stringybark columns, none have failed in two years.

Among green columns allowed to dry, loads of 70 and 60 per cent. caused failure of the eucalypt columns within a few weeks, but some of Douglas fir lasted longer. Under 50 per cent. load some eucalypt columns failed within a few weeks, but others continue to sustain the load after several years.

Six of eighteen eucalypts and six of nine Douglas fir dry columns have failed under 70 per cent. load, in periods similar to those for green columns.

(v) *Scantling Grading.*—Testing continued on 4 by 2 in. jarrah scantling subject to a wide range of defects. Associated experiments dealt with other structural factors.

(vi) *Plywood.*—Karri structural plywood has been tested in bending, tension, and shear, both in the dry and soaked conditions. Associated experiments have been made to determine the effect of temperature on strength, and also gluing characteristics in joints. Charts and other technical information for the design of plywood concrete formwork have been prepared.

(vii) *Poles.*—A total of 270 green poles of messmate stringybark, yellow stringybark, grey ironbark, and jarrah have been tested, together with associated small clear specimens. The mean bending stress at failure of the poles is higher than the mean for standard clear specimens of the corresponding species. No precise correlation can be established between strengths of poles, small clear specimens taken from them, and standard test clear specimens, but generally these green tests indicate that working stresses for design of poles may be increased appreciably over those currently used.

It appears that steam treatment for drying poles can cause very serious loss of strength, but Boultonizing treatment tends to increase strength. A standard-type hot creosote and oil preservation treatment appears to have no significant effect on strength.

(*e*) *Growth Stresses in Trees.*—The study of strain recovery immediately after cutting specimens from the log was continued on two trees of silvertop ash and one of messmate stringybark.

6. TIMBER PRESERVATION.

(Division of Forest Products.)

(*a*) *General.*—Advisory work for Government departments and industry has continued to be a major part of the Section's work, and is steadily increasing in volume as the economic benefits of wood preservation become more widely recognized. This work, together with field tests, surveys, demonstrations, and the publicity given to practical research results, is contributing largely to the development of a wood preservation industry in Australia, with current emphasis on the preservative treatment of poles and posts.

(*b*) *Field Work.*—Field tests have continued to yield valuable results. Tests of radiata pine sleepers, treated in the Division's experimental plant at Melbourne, and installed in various localities in South Australia, were inspected during the year. These extensive tests over a period of twenty years have shown that radiata pine treated with suitable preservatives makes an excellent and durable rail sleeper.

A new pole test has been undertaken in co-operation with the Postmaster-General's Department to determine the most suitable treatment for use against the giant northern termite (*Mastotermes*) in north Queensland. Treatment of several thousand small specimens for a large-scale comparative test of new and old preservatives in New Guinea and various Australian localities has also commenced.

(*c*) *Fence Posts.*—A twin-cylinder portable plant operated by two men and capable of treating at least 60,000 posts annually was designed for use on King Island. This plant of low capital cost is now working most satisfactorily and utilizing small round posts which would otherwise be rejected. Three other plants of this type are projected in different States.

Tests of the sap replacement method were made with promising results for round posts and hop poles freshly cut and barked just prior to treatment. Fixed preservatives of the copper-chrome-arsenic type were absorbed satisfactorily.

(*d*) *Cooling Towers.*—Rapid development of soft rot in Californian redwood used in forced-draught towers has necessitated a study of methods of control by treating the recirculating water. In laboratory tests with partly decayed slats, sodium pentachlorphenate has given favourable results.

(*e*) *Mining Timbers.*—In one mine where conditions favour decay but do not involve any considerable leaching hazard, diffusion treatment of green eucalypt timbers in a concentrated sodium pentaborate solution has been introduced. Some tests of a double diffusion treatment to precipitate copper borate in the wood are also in progress.

Following inspection of a colliery in New South Wales, a proposal for a low-pressure plant using a water-borne preservative has been submitted.

(*f*) *Factors Responsible for Durability of Heartwood.*—Study of toxic substances present in the heartwood of eucalypts and their relationship to the natural durability of the wood has continued. Extractions have been made from three eucalypts—tallowwood, grey ironbark, and silvertop ash, and it has been shown that the substances responsible for durability to decay fungi can be removed by methanol after preliminary extraction with ether. Results have so far indicated that the toxicity of the methanol extracts is well correlated with the decay resistance of the wood. Isolation of the pure toxic compounds has not yet been made. Systematic tests are now in progress to determine the amount and toxicity of extractives in the heartwood of 34 trees of teak from Burma, India, Indonesia, New Guinea, and Thailand, and to correlate results with such factors as silvicultural history, locality, age, rate of growth, and position of the sample in the tree.

(*g*) *Mycology Work.*—In addition to projects already reported, research in timber mycology has included work on the mechanism of fungal attack in wood, the relative tolerance of different fungi to preservative chemicals, the laboratory production of fruiting bodies of wood-destroying fungi, and the laboratory testing of the comparative decay resistance of various Australian and imported timbers. A catalogue of named fungi, maintained in culture at the Division, has been issued.

(*h*) *Miscellaneous.*—Other work has included tests of diffusion treatments of radiata pine building timbers to control decay and termite attack, development of methods for preservative treatment of plywood for Defence Service boxes, tests of various preservatives against the lyctus borer, and the training of personnel to search for possible infestation of imported prefabricated houses by the European house borer.

7. TIMBER SEASONING.

(Division of Forest Products.)

(*a*) *General.*—Special efforts were made through the year to improve seasoning standards in industry. Seasoning costs are some 30 per cent. of production costs, so rewards from this work can be considerable. Active contact with the Seasoning Corresponding Committee of the British Commonwealth Forestry Conference was maintained.

(*b*) *Collapse and Recovery.*—Reconditioning in the 50-25 per cent. moisture content range increased unrecoverable collapse in mountain ash by up to 280 per cent. Unrecoverable collapse was also increased by 18 per cent. of specimen dimension when the temperature of green wood was increased from 130 to 180° F. In alpine ash, greatest gross shrinkage and greatest recovery, but maximum unrecoverable collapse, occurred in butt material.

Collapse in mountain ash was unaffected when wood moisture was replaced by aerated or denucleated water, or by pressure treatments when the timber was green while using saturated or partially saturated carbon dioxide solutions at 50 and 250 atmospheres. An examination of the effects of low concentrations of hydrochloric acid and sodium chloride on collapse in mountain ash, alpine ash, and Israeli- and Australian-grown red river gum was initiated.

(*c*) *Equilibrium Moisture Content.*—Eleven exposure sites were established in Australia and New Guinea for a study to enable prediction of wood equilibrium moisture content (e.m.c.) from weather data.

Measurements of the e.m.c. of wood in use showed a 4 per cent. seasonal range superimposed on a 5 per cent. elevation range (bearers to rafters) in housing components in the Melbourne area, but little variation in wharf decking or piles above water level, which remained about 25 per cent. Railway sleepers retained a core moisture content exceeding fibre saturation point irrespective of season, but surface moisture contents ranged from 8 to 25 per cent. Work on the effect of specimen thickness on the response of timber to changing atmospheric conditions was commenced.

(*d*) *Drying Studies.*—Work on 25-year-old radiata pine scantling timber was commenced. Wood near the pith twisted some five times more than sapwood during kiln drying. Stack weighting was not effective in preventing twist, but final steaming reduced it by up to 50 per cent. For stacks up to 24 feet high, optimum stack spacing was found to be 3 feet. Drying rate and uniformity were more strongly affected by stack orientation than was previously suspected.

Forty 20-feet long mountain ash logs were used for log degrade prevention studies. Cold-application, heavy petroleum greases are giving, in single-coat treatment, better protection than bituminous or paraffin wax preparations. A sprayed protective coat over the ends and tops of air seasoning stacks gave promising results.

Observations were continued on the behaviour of five Australian sleeper timbers pressure preservatized after vapour drying, after air drying, and while green. After exposure periods to up seventeen months, surface and end splitting are least in the vapour dried material. Within a species, drying *in situ* has been approximately inversely proportional to the amount of preservative absorbed.

Work on commercial predrier schedules for Tasmanian and Victorian hardwoods was continued.

(*e*) *Kiln Design and Equipment.*—Predrier design was further developed, and operating conditions within the equipment were investigated. Graphs were prepared to determine heating surface and air velocity required for fast drying of softwoods and veneers.

The screened veneer drier was modified to suit special conditions. Recommendations for improving the air distribution in an imported veneer drier were made. The standard kiln door carrier was redesigned to include mechanical hoisting gear. Performance tests were carried out on kilns in Tasmania, Victoria, and South Australia, and advice for modernizing obsolete kilns in those States was given. Studies on styrene, silicone, and bituminous kiln wall coatings were commenced. Charts showing the effects of fan size and spacing on running costs were prepared.

Plant layouts, and designs for kilns, predriers, conditioning rooms, and reconditioners were prepared for 53 firms and research laboratories in Australia, New Zealand, South Africa, the United Kingdom, the Philippines, Thailand, and Egypt. One hundred and sixteen plant visits were made to assist industry. Wood waste burners were designed for 42 firms in all Australian States, New Guinea, and South Africa.

8. PLYWOOD INVESTIGATIONS.

(Division of Forest Products.)

(*a*) *General.*—Following arrangements with the Australian Plywood Board for cooperative research, the veneer and gluing work was reinstated as Plywood Investigations; the recruitment and training of staff were commenced, and research projects were initiated. Heavy demands for assistance from industry during the year confirmed the need for this work.

Interstate visits were made by officers to study research requirements and to give assistance in peeling, gluing, and veneer drying operations.

(*b*) *Peeling Studies.*—Species peeled included radiata pine, ash type eucalyptus, kauri, red meranti, klinki pine, and red cryptocarya. Methods of determining and recording lathe settings accurately in the laboratory, together with means of establishing these settings in industry, have been successfully developed. The new technique takes into account the behaviour of the lathe during actual operation, and has already been adopted by industry with consequent improvement in veneer production. A study was made of the interacting effects of lathe settings, medullary ray angle, and cross grain on veneer smoothness. Excessive preheating of karri and red cryptocarya prior to peeling increased shrinkage and drying defects of veneers, but not as markedly as in ash-type eucalypts.

(*c*) *Adhesives.* (i) *Tannin Formaldehyde.*—An intensified programme studying mangrove tannin as an adhesive was undertaken. The unfortified adhesive failed to produce adequate wood failure, although shear strengths conformed to specification requirements. Most promising results have been obtained using the tannin fortified with acid-setting phenolic or resorcinol compounds or both, together with wood flour fillers. A semi-commercial trial on klinki pine gave results in conformity with commercial requirements, but some spreading and penetration difficulties were encountered. These have been overcome in the laboratory and a full commercial trial has been arranged.

(ii) *General.*—Several species were reported as giving difficulties with commercial adhesives. Indications are that pH, permeability, and wetting properties are involved. Deleterious effects have been obtained on the gluing properties of coachwood through prolonged heating at controlled humidities, and drying methods were found to have some influence on the gluing behaviour of hoop pine. Assistance was given to wood adhesive manufacturers, both by testing adhesives and by making laboratory facilities available. In cooperation with Preservation Section, testing of the effect of momentary dip diffusion preservative treatments on the gluing behaviour of veneers was initiated. Preliminary results indicated that adhesion conforming to waterproof requirements can be obtained. The effect of moisture content on the rate of temperature rise and bond strength of waterproof adhesives in hot pressing was examined in one species. The time-temperature curves were sigmoidal, flattening a little above 212° F. The higher moisture contents gave lower final temperatures, and at moisture contents of 15-20 per cent. phenolic glue lines were deleteriously affected.

(*d*) *Other Investigations.*—Promising results were obtained in field trials of resistance meters using needle electrodes on both untreated and boron-immunized veneers at moisture contents ranging from ambient equilibrium to 8 per cent. Calibration tests of this and other methods were undertaken with several species in cooperation with Timber Physics Section.

With the wide range of woods used in Australia, drying to a uniform moisture content is often impossible so that overdrying and reabsorption of moisture become necessary. The rate of moisture absorption was therefore studied under ambient, high-humidity, and saturated steam conditions at atmospheric pressure.

Many examples of blemishes in corestock showing through on highly polished face veneers (" telegraphing ") have come under notice. Studies were initiated on factors involving this. It was shown that both knots and cross grain adjacent to knots in radiata pine crossbands affected the smoothness of decorative veneers when panels were subjected to high humidities.

(*e*) *Finishing of Plywood.*—Sections of lauan plywood prepared from veneers cut at various lathe settings, and in collaboration with Wood and Fibre Structure Section, showed that peeling conditions must be carefully controlled to obtain optimum surfaces.

9. UTILIZATION.

(Division of Forest Products.)

(*a*) *Timber Uses.*—Information was supplied on the suitability of timber for 128 uses, and advice given on the properties and uses of 140 species.

(*b*) *Manufacturing Processes.*—The Division is being consulted to an increasing extent on conversion and manufacturing problems. Designs were prepared for ten new saw-mills and four new planing and moulding mills, and the re-organization of two saw-mills. Information was made available concerning log preparation, saw-milling, and finishing equipment. Inquiries were answered on the manufactures of wood for various house components, furniture, turnery, laminated products, and boat building, as well as for re-formed products and disabilities associated with timber use.

(*c*) *Waste Utilization.*—Investigation of fragmented wood as a soil improver, using incubated sawdust-soil mixtures, indicated maximum uptake of nitrogen for radiata pine, red ironbark, and mountain ash of 1.0, 1.4, and 1.6 per cent. of oven-dry wood respectively. They were hardly affected by solvent extraction of the wood, and the agents of decomposition were observed to be microfungi, not basidiomycetes. Maximum uptake occurred five to twelve weeks after mixing, which indicated the need, under field conditions, for gradual application of nitrogenous fertilizer. Release of nitrogen was very slow. Addition of limestone hastened the cycle.

Germination of vegetable seeds of various species on sawdust of mountain ash and radiata pine indicated a depressive effect on seedling development of some species associated partly with high acidity. In the decay residues of radiata pine sawdust, it was found that the solubility of the lignin in dilute alkalis was increased much more by brown than by white rot. The effect of various chemical treatments on rate of decomposition by *Chaetomium globosum* was investigated further. Treatment with boiling water had little effect, but treatment with normal sulphuric acid or alkalis resulted in a marked increase.

Assistance was given with other waste utilization projects, including the production of steam power from wood waste and mangrove bark, the production of shavings-cement blocks, sawdust-resin boards, sawdust briquettes and sawdust-cement floors, and the use of sawdust as a grape-packing material.

(*d*) *Sawing*.—A study of a breast bench with water cooling and peg-type packings indicated that power consumption was not significantly less in this type of bench than in the conventional type, but that greater saw stability made higher feed speeds possible. The possibility that the breaking-down unit might carry out a higher proportion of the sawing, and produce dimensional flitches, is being investigated. To date, the work has revealed considerable surface curvature and hence variation in flitch thickness, due primarily to spring, but also to deficiencies in the log carriage. The technique of coating saw teeth with lacquer and observing the wear was used to study the effects of varying tooth clearance angle and feed speed for a circular saw. The experimental evidence suggested a minimum clearance angle of 6° which is lower than generally accepted, and probably lower than necessary for practical sawing conditions.

The pendulum dynamometer for studying the action of single saw teeth has been further developed and is now capable of registering radial forces.

(*e*) *Standards and Liaison*.—Chairman's duties for the Sectional Committees on Wood Technology of the Standards Association of Australia were carried out. Draft standards were prepared for milled products from south-eastern Australian hardwoods and for house stumps, sole plates, and fence posts. Discussions were held concerning a proposed safety code for saw-milling and woodworking machinery. Liaison was maintained with the F.A.O. Asia-Pacific Forestry Commission, and grading rules for hardwood logs and sawn timber were circulated in Australia for comment.

Assistance was given to a Services panel on packaging where the use of wood was involved, and a specification drawn up for striking-tool handles.

XV. BUILDING.

1. GENERAL.

The building research work of the Organization is undertaken mainly by the Division of Building Research, Highett, Victoria, which collaborates closely with the Commonwealth Experimental Building Station of the Commonwealth Department of Works in New South Wales. Research is directed towards the study of the more effective use of available materials, the adaptation of traditional materials to new constructional methods, and the development of new materials and building techniques for the improvement of both the functional aspects of buildings and the efficiency of methods of construction. A short account of the work of the Division is given in this Chapter; for more detailed information reference should be made to an enlarged annual report issued separately by the Division.

Work on timber for constructional purposes is concentrated in the Division of Forest Products (*see* Chapter XIV.). Work on building foundations is undertaken by the Division of Soils (*see* Chapter II., Section 7), and work on cement and ceramics by the Division of Industrial Chemistry (*see* Chapter XVII., Section 3).

Division of Building Research.—Financial support from sections of the building industry have made possible extensions to the Division's activities in several fields. The Associated Fibrous Plaster Manufacturers of Australia agreed in 1955 to contribute £2,500 per year for a minimum of three years to enable research to proceed on the technical problems of the fibrous plaster industry. The Paint and Varnish Sections of the Victorian and New South Wales Chamber of Manufacturers Ltd., early in 1956, also offered the same amount for research on the painting of plaster surfaces. Unfortunately the initiation of these programmes was seriously delayed owing to the difficulty of recruiting research staff of a suitable calibre. However, two research officers were appointed early in 1957, and both investigations are now progressing satisfactorily.

During the year there was also appointed a research officer who before joining the staff had made a special study of the durability of Victorian freestones. There is evidence of a wide interest in natural stone both for the construction of new buildings and the repair of old ones, and the Division is now able to give advice to quarrymen, architects, and builders on problems arising in the extraction and use of stone.

The year has witnessed major industrial advances in the production of lightweight aggregates for use in concrete and plaster, which the Division has been investigating for several years. The earlier work on perlite (an ultra-light aggregate used with cement or plaster to produce insulating or fire-resistant materials) assisted very materially in the successful production of this material in Australia, but until recently the commercial exploitation of the Division's work on moderately light aggregates had been disappointing. It is pleasing therefore to note that a plant for manufacturing bloated shale is now nearing completion in Sydney, and several firms are well advanced in their planning of the production of moderately light aggregates in Sydney, Melbourne, and Adelaide. In practically every case, developments have been based largely on the work of the Division. Mr. R. D. Hill, who is responsible for the research on lightweight aggregates, was abroad for five months visiting research centres in Europe and India.

The Division has assisted in the implementation of the Colombo Plan by providing training for a number of Asian students.

Officers of the Division delivered lectures to architecture students of the University of Melbourne, and a number of other addresses and lectures to various associations and establishments were given throughout the year. However, with the transfer at the beginning of 1957 of the Royal Melbourne Technical College course in building science from an evening to a day course, it was no longer possible for it to be conducted by the staff of the Division. The annual post-graduate lectures on concrete technology at the Royal Melbourne Technical College again attracted a very large attendance. The Division is represented by Mr. R. C. McTaggart on the newly formed Faculty of Architecture at the Royal Melbourne Technical College.

The Division took part in the building research exhibit at the Building Industries Fair organized by the Builders' and Allied Trades' Association in Melbourne in October, 1956. The Division also collaborated with the Building Research Liaison Service in the preparation of a portable building research exhibit which was demonstrated at Perth.

The Division continued to answer a large number of inquiries on building matters, the total for the year being 5,200, an increase of 6 per cent. over the total for last year.

2. LIGHTWEIGHT AGGREGATES.

(Division of Building Research.)

There is a pronounced world-wide trend to lighter building construction, and one of the most promising ways of achieving this is by the use of lightweight aggregates in concrete and plaster for structural and fire-proofing purposes. Consequently research on the production and properties of these lightweight aggregates has been continued, notably on bloated clay and shale for concrete and perlite for both concrete and plaster.

(*a*) *Expanded or Bloated Clays and Shales.*—As a result of the renewed interest in expanded or bloated clay and shale aggregate a considerable amount of testing has been carried out on clays and shales from sites near Melbourne and Sydney, and additional sources of suitable bloating materials have been located.

The concrete making properties of several samples of bloated clay aggregate have been examined. With aggregates of low absorption (less than 10 per cent.) it has been found that presoaking of the aggregates is unnecessary and that higher concrete strengths are obtained if the aggregate is added dry to the mix.

(*b*) *Perlite.*—Perlite is an artificial lightweight aggregate made from volcanic glass. It is being produced commercially in Melbourne and Sydney and is now widely used as an aggregate, particularly in plaster for fire-resistant construction.

Recent studies of perlite have been concerned chiefly with the examination of about 50 samples of ore collected during a systematic survey of the ore deposits in the New South Wales-Queensland border area.

The experimental work on perlite concrete, a lightweight insulating material made from portland cement and perlite, has now been completed, and a large amount of information on its strength and other physical characteristics has been obtained.

Considerable attention has been directed to the study of the secondary expansion of plaster containing perlite, and recent results confirm the earlier findings that no undesirable forces or deformations should arise from the use of materials at present available in conventional forms of construction.

3. CONCRETE INVESTIGATIONS.

(Division of Building Research.)

(*a*) *Theory of Rupture of Concrete.*—It has been established that microcracks develop in loaded unreinforced concrete specimens before the load at which they ultimately fail is reached, but there does not appear to be any relationship between the cracking load and the ultimate load.

The earlier investigations have continued with tests on beams of weaker concrete, but there is again no evidence that the formation of microcracks is promoting failure. The type of aggregate used in the concrete appears to have little influence on the strain at which cracking commences.

(*b*) *Shrinkage and Cracking Studies.*—The shrinkage of concrete cured in carbon dioxide immediately after demoulding is about 75 per cent. less than that of concrete cured under ordinary atmospheric conditions.

To find an explanation for this effect a study is being made of the way the carbon dioxides is bound to the cement. Thermal analysis indicates that carbon dioxide is held in the form of simple carbonates of all the main metals in the cement, and this suggests that some of the normal cement minerals are broken up by the action of the gas. An attempt is now being made to relate the shrinkage and strength characteristics of the concrete to the amount of the different carbonates present.

The object of the study on cracking in concrete is to find the cause of the "prehardening" cracks that are frequently reported to appear on concrete shortly after it is poured and before it has hardened. The work so far indicates that the fundamental cause of the cracking appears to be differential rates of settlement or bleeding.

(*c*) *Calcium Silicate Hydrate.*—Calcium silicate hydrate is a new type of building material that is being investigated at the Division. It is not yet being produced in Australia, but if it were developed commercially it could play an important part in the constructional field in the form of precast structural units.

Studies of the material have shown that exceptionally high compressive strengths at given densities may be obtained. For example, compressive strengths of about 6,000 lb./sq. in. have been obtained for material of 60 lb./cu. ft. one day old.

4. BUILDING STONES.

(Division of Building Research.)

From the number of inquiries received it is clear that there is still considerable interest in natural stone, either for new buildings or for the restoration of old ones. In this project reliable information, particularly in relation to durability, on the properties of freestones in Victoria is being assembled.

5. GYPSUM PLASTER INVESTIGATIONS.

(Division of Building Research.)

(*a*) *The Setting of Plaster.*—As part of the general study of the physical chemistry of calcium sulphate attention is being directed to the study of the mechanism of the setting of plasters.

This study is being approached from two angles; firstly, that of the changes in composition of the calcium sulphate hydrates present, and secondly, that of the development of the crystalline structures. In the study of the changes that take place in the composition of the hydrates of calcium sulphate, it has now been found that a considerable quantity of gypsum is formed by the time the initial set is reached and that this varies inversely with the initial consistence of the plaster-water slurry, i.e. an initially thick mix requires the formation of less gypsum in order to produce the degree of stiffening termed initial set than does an originally thinner mix.

The formation of small quantities of gypsum crystals appears therefore to be sufficient to explain the phenomena known as initial set.

For the study of the development of gypsum crystals during setting a technique using a projection microscope has been developed.

(*b*) *Structural Gypsum Plaster.*—A thorough and systematic examination was made of the performance of houses with load-bearing gypsum plaster walls, now about 10 years old.

The general condition of those examined was found to be good, and no serious structural defects were revealed. Any defects that could be found, in the form of cracking, seemed most likely to have occurred at the time of erection.

Work in the laboratory has been concerned with the behaviour of structural gypsum over long periods so as to provide detailed information for design purposes of its physical and mechanical properties.

Particular attention is being paid to the creep of gypsum plaster because long-term tests have shown that the design and performance of structural gypsum is greatly complicated by the pronounced creep characteristics of the gypsum.

Arising from the need to specify conditions of test for the quality control of structural plaster, an examination has been made of the effect of varying storage conditions on the strength and dimensional changes of cast gypsum.

6. FIBROUS PLASTER INVESTIGATIONS.

(Division of Building Research.)

The contribution by the Associated Fibrous Plaster Manufacturers of Australia for research on the problems of the fibrous plaster industry has made it possible to appoint a research officer who can devote his whole attention to this work.

The work has been begun by a survey of the fibrous plaster industry in the eastern States, and the major problems have been defined and discussed with a committee appointed by the manufacturers.

The formation of black stains on fibrous plaster is a trouble that has been reported on several occasions. Some of these stains have been traced to the corrosion of the clouts used for fixing when they are in contact with wet fibrous plaster sheets.

7. PAINT ON PLASTER INVESTIGATIONS.

(Division of Building Research.)

With the assistance of the Australian paint industry it is now possible to start work on decoration of plaster surfaces in general. A research officer who is engaged full time on the project has commenced duty and is working on a programme agreed upon by a committee of the manufacturers.

8. CLAYS AND CLAY PRODUCTS.

(Division of Building Research.)

(*a*) *Regional Studies of Australian Heavy Clays.*—Up to the present, studies of clays from Brisbane, Sydney, Perth, Tasmania, and central Victoria have been completed, and that of the clays from Melbourne and adjacent areas has been begun. Papers on clays from Brisbane, Sydney, and Tasmania have already been published, and the results of the mineralogical and particle-size distribution studies of the clays from the metropolitan area of Perth are now being collated.

Progress has been made in the examination of the mineralogy and particle-size distribution of the tile and brickmaking clays from Melbourne and adjacent areas in Victoria.

(*b*) *Expansion of Clay Products.*—The work already in progress on the expansion of bricks and roofing tiles when exposed to water has been extended to other types of clay product and to the whole of the Australian clay products industry also.

Generally speaking, the lower burnt products expand more readily on standing, soaking, or autoclaving, but the higher burnt ones eventually show a greater expansion on autoclaving.

(*c*) *Durability of Clay Roofing Tiles.*—The study of the deterioration of clay roofing tiles, of particular significance along Australian sea fronts, originally undertaken at the request of the Roofing Tile Manufacturers' Association of Victoria, was extended in its scope during the year in co-operation with the Australian Clay Products Association to cover the whole of Australia. In a second progress report on the problem, now being distributed to clay manufacturers, an account is given of recent developments in the investigations and some practical solutions are suggested.

(*d*) *Industrial Potentialities of Clay Materials.*—During the year 53 clays and shales from various parts of Australia and New Guinea were received for investigation. Pilot-plant and laboratory studies have been completed on many of them, and recommendations made concerning their suitability for making bricks, tiles, pipes, &c.

(*e*) *Plant and Equipment.*—Many structural clay products works in Australia have been experimenting with oil firing, but so far the results obtained have not been completely satisfactory. Investigations by officers of the Division have shown that these problems are mostly related to attempts to superimpose oil firing directly on the conventional kiln as designed for coal firing, to the incorrect lining of the combustion chambers, and to the incorrect types of burner. Suggestions for improvement have been made and sketch plans for designs for oil-fired downdraught kilns have been fairly widely circulated.

At the same time the Division has discussed with industry the more economical use of coal by means of regular feeding with automatic stoking, and the introduction of hot-face insulation of kilns. The possibilities of saving some 50 per cent. in coal consumption and considerable shortening of the burning cycle of the conventional type of downdraught kiln has been demonstrated by the Division's work in co-operation with the New South Wales State Brickworks and by overseas experience. Further consideration has recently been given to a continuation of the work on these experimental kilns, which has unfortunately been in abeyance for some time.

9. LIME AND LIME PRODUCTS.

(Division of Building Research.)

With the completion of the studies on the correction of unsoundness in magnesium limes, formal research on lime is being discontinued until such time as the demand for further work arises. However, the survey of the lime industry and its resources, started some years ago, will be continued as time and opportunity permit, and advice and assistance to manufacturers and those interested in lime and its products will still be given upon request. Papers describing the results of the studies and the method for correcting the unsoundness have been published.

10. BITUMINOUS ROOFING MATERIALS.

(Division of Building Research.)

(*a*) *The Analysis of Roofing Felts.*—A considerable amount of work has been done to assist the Standards Association of Australia in drawing up a standard for bituminous roll roofing materials. In general the methods of test are based on those of the American Society for Testing Materials, but some improvements have been suggested.

The methods proposed by the Division have been tentatively accepted for inclusion in the standard.

(*b*) *Shrinkage of Paper-based Roofing Felts.*—It has been observed that considerable shrinkage of paper-based roofing felts can occur in service. It is believed that this is associated with moisture and the large change in viscosity of the bitumen adhesive with change in temperature. The problem is being investigated by the exposure to the weather of a number of samples of raw, saturated, and coated paper felts of known fibre furnish laid on a built-up roof membrane with various grades of bitumen and also without any adhesive. Materials based on asbestos and glass fibre have been included in the experiment. The change in dimensions of all samples is being measured at monthly intervals and is being correlated with rainfall and air temperature. The paper materials are showing greater movement than the asbestos materials, which in turn are showing greater movement than the glass fibre materials.

(*c*) *Aluminium Foil for Flat Roof Surfacing.*—Aluminium foil is being widely used as a heat-reflective finish for flat roof membranes, but there have been cases where troubles such as creep, buckling, and corrosion have occurred. To examine the influence of various factors, such as length and thickness of aluminium foil and strip *versus* solid sticking, an experimental membrane, consisting of an aluminium foil surfacing over two layers of felt, was laid at the Division.

After twelve months' exposure it has been found that the method of attaching the first layer of the felt to the deck seems to have little influence on the creep of the foil. This creep or permanent expansion is believed to be associated with the high coefficient of thermal expansion of aluminium and the restraint to contraction offered by the cold bitumen.

(*d*) *Roof Membrane Maintenance.*—Some of the experimental roof membranes covering buildings in the grounds at Highett are now over eight years old and provide an excellent opportunity to test different methods of maintenance. Overseas reports indicate that clay-stabilized bituminous emulsions, reinforced with glass fabric if the surface has deteriorated badly, are very satisfactory as a maintenance treatment. Sections of aged roof membranes have been treated with combinations of two different clay-stabilized bituminous emulsions and three different reinforcements, viz., open weave glass cloth, felted glass tissue, and rot-proofed hessian. The performance of these is being observed and compared with other sections where hot bitumen has been used to bond a layer of coated paper felt, coated asbestos felt, or saturated asbestos felt.

11. Glass and Glazing.

(Division of Building Research.)

During the period under review a firm of architects arranged for an officer of the Division to attend a conference in Washington on the use of glass in the exteriors of building and to investigate some aspects of curtain-wall construction in the United States of America with particular attention being paid to the prevention of cracking of coloured glass and the sealing of curtain walls against rain penetration.

The visit to the United States confirmed that the surest way to eliminate such cracking was to " toughen " the glass. By this process the surface layers of the glass are placed in a state of compression, and the glass is essentially prestressed and has a much higher breaking strength.

Some experiments have been made in the laboratory to compare some different types of sheet glass as to the risk of cracking when subject to thermal gradients. Significant differences between different types of glass were obtained.

12. Glazing Compounds.

(Division of Building Research.)

A study of non-hardening glazing compounds has been undertaken as an extension of earlier work on caulking compounds. In particular it is intended to measure the rheological properties of various formulations after periods of exposure to natural weather conditions. This work is important because non-hardening glazing compounds are required that can maintain good adhesion to both glass and metal frame and be capable of deforming without rupture.

13. Thermal Investigations.

(Division of Building Research.)

During the winter of 1956 a study was made of the thermal behaviour of three buildings in the grounds of the Division. Two of these buildings, which are identical tiled roof and weatherboard structures except that one has a conventional suspended timber floor and the other a concrete slab floor on the ground, had been used during the preceding winter for an investigation to compare the effects of these two types of floor on the thermal conditions of houses.

The work has been extended to an examination of the effects of glazing on the thermal conditions in a house by taking measurements on a third building which is of " solar " design, having a large glass wall facing slightly east of north, a concrete floor on the ground, weatherboard walls, and a flat roof. The most notable feature of the results was that, almost without exception, the temperature in the solar hut was at all times of the day higher than in the others.

Some time ago a mathematical treatment was evolved at the Division for calculating the internal temperatures in houses and other buildings exposed to fluctuating external temperatures. To provide an intensive check on this calculation method, considerable data on internal temperatures in the three buildings and on the external conditions have been obtained over two periods of four days.

14. Architectural Acoustics.

(Division of Building Research.)

The work on architectural acoustics has as its objects the rationalization of the design of concert halls and auditoria and the study of the performance of acoustical absorbents and duct filters.

The reverberation-time method usually employed for designing concert halls and auditoria is far from satisfactory, but it seems likely that a better test might arise from a consideration of the echo pattern in a hall since all the common sounds consist of a direct sound followed by a succession of echoes. This possibility is being examined by listening tests in which the reaction of listeners to a variety of sounds with and without artificial echoes is determined.

These subjective acoustic studies have been extended during the year with combinations of a sound and an echo to which " natural " reverberation is added by means of a speaker-microphone combination in a reverberant room. Speech, string and organ music, as in the earlier work, and short pulses of noise, of both high and low frequencies, were used.

The calculation of acoustic transmission along ducts which include bends and changes in cross section is usually a tedious and difficult process. Studies made with modifications of the impedance tube that is used for measuring the specific acoustic impedance of absorbing materials have led to the simplification of such calculations.

XVI. WOOL TEXTILES.

1. General.

An extensive programme of research has been undertaken with the aim of improving the use of wool as a textile fibre. This work is complementary to research in sheep husbandry, described in Chapters V., VI., and VII., which is aimed at increasing the quality and production of wool. The major aims of wool textile research are: (i) to increase the knowledge and understanding of the complex structure of the wool fibre and its physical and chemical properties; (ii) to use this knowledge to improve wool as a textile fibre, to improve technology in wool processing, and to utilize by-products more fully; (iii) to improve machinery used in wool textile manufacture. In these ways it is hoped to preserve wool's unique position amongst the world's textile fibres.

The Organization's work in this field has been distributed among three Wool Textile Research Laboratories, as follows:—

(i) The Melbourne Laboratory at Parkville is responsible for research on the structure and chemistry of wool and on some related wool processes.

(ii) The Geelong Laboratory at Belmont is primarily responsible for technological investigations.

(iii) The Sydney Laboratory at Ryde carries out research on the physics of wool and on the physical and engineering aspects of wool processing.

The overall policy of these Laboratories and the co-ordination of wool textile research is the responsibility of the Wool Textile Research Committee. This Committee is comprised of the Officers-in-charge of the three Laboratories, and it constantly reviews research programmes to ensure that for each project the best use is made of available personnel and facilities. It also arranges if necessary for joint study on a project at two or all three of the Laboratories.

The Division of Industrial Chemistry has continued a study of the constituents of wool wax and possible ways of utilizing them or their derivatives (*see* Section 4 of this Chapter). It is also studying the structure of proteins in relation to wool (*see* Section 10 of this Chapter). The

Division of Entomology is continuing to study the digestive processes of wool-eating insects and larvae (*see* Chapter IX., Section 2 (a)).

Wool Textile Research Laboratories.—In general the lines of research followed in the Laboratories during the past year resemble those reported for the previous year. A new project has been commenced in conjunction with the Division of Animal Health on footrot in sheep. It was felt that resources developed for research on wool proteins might be applied with advantage to studies on the bacterial destruction of proteins of the sheep's hoof in footrot.

Research on the degradation of cellulose by fungal enzymes has been diverted from the problem of protecting tent canvas against attack by moulds, and will be linked by arrangement with the Division of Plant Industry with research on the digestibility of pasture plants by sheep.

Two important developments have followed the successful International Wool Textile Research Conference held in Australia in 1955. Firstly, the 130 papers and ten lectures have now been edited and published in a series of six volumes. In this way a valuable fund of information on wool textile research has been made permanently available, not only to delegates to the Conference, but to others working on wool and related subjects throughout the world. Secondly, an excellent opportunity has been provided for the Wool Textile Research Committee to review the Australian wool research programme in the light of overseas research in this field. It has become clear that the main burden of wool textile research falls increasingly on Australia, since the provision overseas for wool research is limited and certainly not commensurate with the importance of the industry. Further, it is apparent that whereas research on the physics, chemistry, and structure of wool is impressive, research on wool textile processing needs much more emphasis.

To establish closer contact between the Organization's research workers and the Australian wool textile industry, a meeting was held at the Melbourne laboratory in May which was attended by members of the Executive of the Associated Woollen and Worsted Textile Manufacturers of Australia. Early in 1957 the Wool Textile Research Committee also visited leading clothing manufacturers in Sydney and Melbourne to ascertain what properties are required in wool fabrics by the clothing industry. As a result of these visits research designed to improve the dimensional stability of fabrics will be intensified in the various research programmes.

It is gratifying to note the extent to which processes already developed in the Wool Textile Research Laboratories have been adopted by the wool industry; for example, those relating to branding fluids, the solvent degreasing of wool, carbonizing, melange printing, mothproofing, and shrinkproofing. It is desired, too, to acknowledge gratefully the co-operation and facilities which have been so readily extended by local industry to the research staff in connexion with large-scale trials which must precede any recommendation for the industrial adoption of a new process.

The growing awareness of the importance in wool transactions of the moisture content of wool led to the appointment of a Wool Testing Investigating Committee which included representatives of the Australian wool buyers, wool brokers, wool scourers, the Department of Primary Industry, and the Organization to examine the matter. A technical report on the establishment of wool testing facilities, prefaced by a Wool Textile Research Laboratories officer, has provided the basis for some of the recommendations to the Commonwealth Government for the establishment of an Australian Wool Testing Authority.

The Officer-in-charge (Dr. M. Lipson), of the Geelong Laboratory, on return from a visit overseas, has reported on the most important fields for Australian wool textile research in the light of overseas requirements and activities in the fields of man-made fibres. Co-operation with the Wool Industries Research Association (W.I.R.A.) in Great Britain has been strengthened by the exchange of a physicist attached to the laboratories of the Association with a physicist from the Sydney Laboratory. The W.I.R.A. officer will work in Australia on the penetration of dyes into wool, and the Sydney officer will study the breaking strengths of fibres in the W.I.R.A. laboratory.

Two research chemists from the Melbourne Laboratory have held research fellowships during the year in United States of America universities, one at the University of Wisconsin and the other at Cornell University. A research physicist from the Sydney Laboratory has held a scholarship at the Graduate School, University of Utah, Salt Lake City, Ithaca.

Within Australia co-operation with the New South Wales University of Technology has continued, officers being stationed in the Schools of Applied Chemistry and Applied Physics. Joint research on strains and changes in shape of fibres during worsted processing is being pursued in conjunction with the School of Textile Technology. A stand was prepared and manned for the Royal Adelaide Exhibition illustrating the role of the scientist in wool textile research and various C.S.I.R.O. achievements in this field. The exhibit was awarded a bronze medal in recognition of its high standard.

A two-story building, the first permanent laboratory to be constructed on the Wool Textile Research Laboratories site in Sydney, has been completed during the year and is now occupied.

2. RAW WOOL.

(Wool Textile Research Laboratories.)

(*a*) *Wool Quality in Relation to Properties of Fabric.*—Five 200-lb. lots of wool having specified mean fibre diameter, crimp, and fibre length have been selected in co-operation with the Division of Animal Health and supplied to the Textile Research Institute at Princeton, United States of America, for an investigation of the influence of these fibre characteristics on the properties of the fabric. In a previous study of this kind during 1952-56, wools of the same diameter and corresponding to 64's count but differing in crimp were supplied to the Institute by these Laboratories. The results showed that the wool having the greater number of crimps per inch can be spun to a slightly finer count and yield cloth having a slightly softer handle than the wool having the smaller number of crimps per inch.

(*b*) *Branding Fluids.*—" Si-Ro-Mark " branding fluid has been widely adopted in Australia. Over 250,000 gallons of the fluid have now been marketed by the 28 firms licensed by C.S.I.R.O. to use the trade name, and it is now also being produced and used in several other wool-growing countries. Variation in consistency and some separation in commercial fluids, reported during the first season to occur during storage at high temperatures, were found to result from variation in the lanolin used in making the fluid. This difficulty has now been overcome by introducing a slight modification in the formula which has been adopted by all manufacturers. As a result of the extended use of " Si-Ro-Mark " branding fluid, there is now little trouble in woollen mills either in Australia or overseas due to the presence of " tar " in Australian wool. Formerly this was a serious problem.

(*c*) *Solvent Degreasing.*—The solvent degreasing process is now in commercial operation on a two-shift basis in one Australian mill where a plant has been constructed capable of treating approximately 2,000 lb. of greasy wool per hour. Arrangements have been finalized for the construction of another unit to be set up in a mill in Bradford; this will be used for commercial production, and will be available to demonstrate the method to other interested firms overseas. Meanwhile the pilot plant used in the investigations has been modified to give a much higher production rate than in earlier trials. Using a special arrangement to provide a denser feed, the throughput of the plant has been trebled and disturbance of the wool reduced. The product is therefore more satisfactory in subsequent processing. This finding will have a marked influence on the design of commercial units, and the plant being set up in a Bradford mill will incorporate this and other improvements.

Previous results on the processing performance of solvent degreased wool have been confirmed. In a series of industrial trials, the solvent degreased wool has in all instances given more top and less noil. There are also indications of higher yields and better colour in the tops obtained by solvent degreasing.

(*d*) *Burr in Wool.*—Trials on rugging sheep for protection against burr are now being concluded. Wool from rugged and unrugged sheep run under the same conditions has been processed to fabric and the two products compared at all stages of manufacture. Although the complete results are not yet to hand, the rugged wool has shown less burr and wastage during manufacture and in all instances has commanded a higher price than the unrugged wool. It would appear that the adoption of rugging wool will depend on whether a rug can be used for two seasons. The cost of a rug would be more than covered by the increased return on wool shorn during two seasons but not in one.

Mill trials have fully confirmed the laboratory experiments in showing that the addition of non-ionic detergent to the sulphuric acid bowl at the rate of ½-1 lb. per 100 gallons significantly reduces damage to the wool fibre during carbonizing. In a series of six trials at various mills the addition of detergent has increased the yield by 5 per cent. over that obtained in its absence. This improvement is attributed to a reduction in the number of fibres broken and lost with the charred vegetable matter in the willey. Further evidence of the protection against fibre damage by the detergent is the greater strength of the yarn obtained and the consequent reduction in ends down during spinning.

On current prices the expenditure of ¼d. for sufficient detergent to treat each pound of wool yields 3¾d. worth of additional wool fibre. Already about half the carbonizers in Australia are using the improved process. If its use was extended to all carbonizing type wool produced in Australia, the improved yield alone would be worth £1,000,000 annually. In fact a good deal more wool than that normally listed as carbonizing type is carbonized, and the total saving would therefore exceed this estimate.

3. FLEECE BY-PRODUCTS.

(Wool Textile Research Laboratories.)

The flotation recovery method for lanolin has been improved and a modified pilot plant has been constructed and installed in a local worsted mill to allow its performance to be observed under continuous operating conditions. In the meantime an additional plant has been installed bringing the total to four commercial units now in operation in Australia.

Experiments are in progress to purify the lanolin which is produced in excellent yield as a by-product of the solvent degreasing process. A higher price for the lanolin recovered could make the solvent process particularly attractive.

4. DERIVATIVES OF WOOL WAX AND SUINT.

(Division of Industrial Chemistry.)

Attention is now principally directed to the long-chain acids of the wax and to lanosterol. One of the possible uses for the acids is in the preparation of plasticizers, for which the plastics industry has large and increasing requirements. Before preparing selected esters from the wool-wax acids for evaluation as plasticizers, some time has been spent in finding the best way of preparing the acids essentially free of the associated aliphatic alcohols. The methods so far devised for separating the hydroxy acids from the total acid fraction are not suited to large-scale working, and so the first esters were prepared from the whole acid fraction. Higher esters have been prepared both directly from the acids and by trans-esterification of the methyl esters.

An attempt has been made to extend the work on the conversion of lanosterol to physiologically active compounds by the preparation of a deoxycorticosterone analogue. Because of difficulties in applying the conventional reactions of steroid chemistry to lanosterol, only an impure fraction has so far been available for testing; this has shown some biological activity similar to that of deoxycorticosterone.

The Wolff-Kishner reduction of 7, 11-diketones derived from lanosterol, an important early step in the preparation of these hormone analogues, has given abnormal results necessitating a closer study of the reaction. The origin and structure of the by-products has now been determined.

Progress in the examination of suint has been delayed pending a staff replacement. Meanwhile, the gas-chromatography equipment being developed and constructed in the Section mainly for this work has been completed. One unit accommodates three small columns containing different liquid phases and a larger unit houses a preparative column. Either of these units can be connected to a gas density balance which is a considerably modified form of the Martin and James design.

5. WOOL TEXTILE PROCESSES.

(Wool Textile Research Laboratories.)

(*a*) *Yarn Manufacture.*—A considerable amount of attention has been devoted to the simplification of the conventional techniques of worsted processing. Research has been concerned with the processing of solvent degreased wool which is much less entangled than normally scoured wool and therefore requires less opening. The amount of worsted carding applied to this product can therefore be greatly reduced and the speed of carding increased. Another phase of the research aims to eliminate carding from worsted processing, and this again has been concerned in particular with solvent degreased wool. A converter system has been developed for the purpose in which modified gill-boxes replace the card in the preparation of the worsted sliver. Worsted tops have been obtained with this system, from solvent degreased Merino wool, with considerably less wastage than in the usual method based on carding.

The work on worsted lubricants has progressed satisfactorily and some mill trials have been undertaken. These preliminary experiments indicate that it should be possible to develop lubricants which are more effective and cheaper than those normally employed.

An autoleveller has been developed to eliminate excessive fluctuations in production and tear which, although not generally recognized, have been detected during the normal running of a Noble comb. A prototype fitted to a Noble comb at the Geelong Laboratory has caused marked improvements in the performance of the machine. Short range variations in output-weight and tear have dropped from ± 11 and ± 12½ per cent. to ± 2 and ± 5½ per cent. respectively. The average output between comb loads during continuous running has varied by less than ± 0.5 per cent. compared with ± 10 per cent. for the comb without autoleveller. Trials are to be undertaken with several of these devices under practical running conditions in local mills.

In the field of worsted spinning, research has continued on the development of an autoleveller which operates at the output end of the machine. This eliminates variations introduced by the machine itself which are not controlled in existing commercial autolevellers which measure at the input. The new device assesses variations in weight of roving as it enters the front rollers of a spinning frame and corrects these by altering the speed of the rollers as the wool passes through. With this equipment, which uses a capacity measure of levelness, it has been possible to produce a more uniform worsted yarn than obtained hitherto by any other method. Research is in progress to replace the capacity measuring device with a mechanical method of measuring fluctuations, since this would require less maintenance under practical operating conditions.

A new type of yarn evenness tester based on the principle of a transversely vibrating yarn whose resonant frequency is a measure of the weight per unit length of the yarn has also been constructed. Comparison of the estimates of yarn evenness obtained with this tester with those obtained with a tester of the capacitance type and by weighing short lengths of fibre show the new tester to be accurate and stable. It may be cheaper to build than existing electronic types.

(*b*) *Felting.*—A simple laboratory machine has been developed which enables the felting of fur fibres and wool fibres to be easily followed. When applied to various samples of wool it was shown that those having little crimp, for example, from sheep fed on copper-deficient pasture or from straight wool mutant Merino sheep, felted more rapidly than well-crimped samples. Industrial trials indicate that up to 20 per cent. of the rabbit fur in felt hats can be substituted with crimpless mutant Merino wool without appreciable loss in quality.

(*c*) *Dyeing.*—Further studies have been made of the surface properties of pure wool proteins when spread in a monomolecular film on a solution of known ionic strength and pH and allowed to react with a dyestuff solution injected beneath. In the early experiments the acid dyestuff Orange II. has been used. The results are being correlated with the reaction of the same dyestuff with the same wool protein in bulk solution and with the intact wool fibre. Studies with surface films of wool proteins eliminate interference by histological factors encountered in experiments with the intact fibre and by configurational factors which interfere when the proteins are coiled or aggregated in bulk solution.

Laboratory experiments have shown that the introduction of a small amount of benzyl alcohol into the paste used in the melange printing process, together with increased pressure in steaming, allow reductions to be made in the steaming time and better colour values to be obtained in wool printed with a given amount of dye. The new process is already being used in the wool textile industry both in Australia and overseas.

Fibres which have been modified by exposure to ultraviolet light take up certain classes of dyes more readily. This change in properties is being carefully examined to see if it has commercial application.

6. Modification of Wool.

(Wool Textile Research Laboratories.)

(*a*) *Shrinkproofing.*—Investigations on the treatment of woven fabrics with casein have continued with the object of devising an inexpensive method of shrinkproofing using aqueous solutions. The main problem has been to develop a cheap method of cleaning the fibre surface before applying the casein. The most satisfactory method is to treat with alcohol or alcoholic alkali. However, there are objections to using solvents in the wool textile industry, and suitable aqueous reagents are therefore being sought. Certain oxidizing agents and detergents show promise of producing the desired result.

The "Si-Ro-Fix" process, based on the use of alcoholic alkali and a resin derived from nylon, continues to be used commercially for shrinkproofing socks. Experiments have also been undertaken to adapt the method for the continuous processing of blankets. Evaluation of treated blankets at a Victorian hospital shows that the process should treble their life under the severe washing conditions to which they are subjected in hospitals.

Experiments have been carried out using aqueous alkali in the presence of various salts to shrinkproof wool. Sodium hydroxide in the presence of thiosulphate was the best of the reagents tested, but the high concentrations and consequent expense of the salt required would preclude its adoption by industry.

(*b*) *Mothproofing.*—Dieldrin is being widely used in Australia for protecting wool against insect attack, and its use is extending also to countries overseas. The name "Si-Ro-Moth'd" has been registered as a trade mark by C.S.I.R.O., and approved firms are being licensed to use this mark on goods treated with dieldrin according to the recommended procedure. Dieldrin is convenient to apply and cheap; it should largely overcome one of the major disadvantages of wool. It is applicable to most goods except those which are frequently washed, such as underwear and babies' wear. These, however, would rarely need mothproofing.

Certain inorganic salts, particularly lithium compounds, have also been found capable of preventing moth larval attack. This is apparently because the larvae are unable to detoxify such compounds by the formation of insoluble sulphides, which is the mechanism used by these larvae to detoxify the salts of other metals.

The reaction of wool with formaldehyde under alkaline conditions has been shown to enhance its resistance to alkali and to protect it from moth larval attack.

(*c*) *Permanent Pleating.*—Permanent set in wool has been shown to require hydrogen bond and disulphide breakdown but not rebuilding of linkages involving reduced disulphide bonds.

Permanent pleating has been investigated using alkaline conditions which are known to produce permanent set in single fibres. It has been found that for the permanent creasing of pure wool fabric the treatment must be carried out in association with a shrinkproofing treatment, since the felting of wool during washing tends to mask the crease. It has been possible to obtain a satisfactory permanent crease by maintaining alkaline conditions in a fabric while it is held under the Hoffman press for longer steaming times than those normally employed.

To examine microscopically the arrangement of yarns and individual fibres at the crease in a cloth, and to assess the strains in the fibres, a suitable embedding medium has been evolved which enables sections of the crease to be cut in the microtome. This information will help in determining what mechanical properties in fibres are required for the production of durable creases.

(*d*) *Assessment of Wool Damage.*—One method of detecting wool damage of the type which could occur during manufacture is to estimate its amide content since these groups are among the first to be destroyed when wol is heated with acid. For this purpose the wool should be digested by heating with 2N HCl at 100° C. and samples taken at intervals for steam distillation of the ammonia into boric acid following the addition of alkali. The results for amide content are then extrapolated back to zero time. Another change accompanying the destruction of wool with acid but which proceeds at less than one-tenth of the rate of amide destruction is the liberation of aspartic acid. With weak acids more than 50 per cent. of the available aspartic acid has been shown to be released before other free amino acids can be detected. An improvement has been made in the hydrazine method of identifying the terminal amino acids exposed when the peptide chains in wool proteins are split, and this is being applied to study the effect of certain shrinkproofing agents.

The trypsin digestibility method of assessing wool damage has revealed that disordering of wool proteins is liable to occur during treatment with alkali, especially in the presence of fatty acids, as for example when scouring for an extended period. Although these changes are partly reversed by acid, wool in this condition could be seriously damaged in later stages of processing.

7. PHYSICS OF WOOL AND FIBRE ASSEMBLIES.

(Wool Textile Research Laboratories.)

(*a*) *Mechanical Properties of Single Fibres.*—The aim of the research into the mechanical properties of wool is to explain them fully and ultimately in terms of the molecular structure. It is expected that from this work will emerge new ways to improve wool processes and products.

The theoretical model, developed to explain the mechanical behaviour of wool in water for extensions from 3 to 30 per cent., has been developed further to cover the small extension range known as " Hookean " for both wet and dry fibres over a wide range of temperatures.

Studies have been undertaken on the extension of wool fibres and their setting at new lengths, either temporarily or permanently, depending on the time and temperature used. This property is of great textile importance since it is the basis of such cloth finishing processes as crabbing, blowing, and permanent pleating. Improvement in set would also reduce the relaxation shrinkage of a cloth when wetted or steamed. When steamed under tension and then allowed to relax, or when treated with certain chemicals, wool fibres shorten to less than their original length. The structural changes in the fibres accompanying this shortening or " supercontraction " are related to those producing set, and the two phenomena are therefore being studied together. Supercontraction of wool with lithium bromide produces rubber-like properties, and theories for rubbers have now been applied to wool in this state. Traces of bromine in the lithium bromide inhibit supercontraction, and wool irradiated with ultraviolet light supercontracts at an increased rate. The change in the X-ray diffraction pattern of wool during extension, corresponding to the conversion of coiled α-keratin to uncoiled β-keratin, has now been shown to commence below the 20 per cent. level. This was formerly believed to be the lowest extension at which β-keratin appears. Another finding which conflicts with the accepted view is that when wool fibres are stretched the rate of appearance of β-keratin does not correspond with the rate of disappearance of α-keratin.

(*b*) *Electrical Properties.*—The electrical properties of wool are being studied for the information which it may yield both on wool structure and on the mechanism of electrical conduction in wool, and for the help which it may provide in controlling static charges during processing. The studies involve measurements of the electrical conductivity, dielectric constant, and dielectric loss of wool under varying relative humidities and while being stretched.

The mechanical forces which can be applied to wool fibres by means of electric fields were found to be limited by corona discharge. No immediate application of such fields in processing is apparent.

(*c*) *Regain in Wool.*—Research has continued into processes whereby wool gains and loses water, into the practical problems of drying or conditioning wool, and into methods of measuring or controlling regain (water content expressed as a percentage of dry weight).

Apparatus developed to follow weight changes in single wool fibres has provided data on the rate at which both fine and coarse fibres gain or lose water with change in the relative humidity of the surrounding air. Short-period and long-period effects have been discovered. Particular attention is being given to the long-period effects in which the final regain is not reached for about a day, when small changes in relative humidity are applied. The effect is to be partly explained in terms of the mechanical stresses due to the swelling of wool when water is absorbed.

The penetration of liquid water into wool fibres, as followed by photography under the microscope, has been found to vary with the type of sheep, but the epicuticle appears to offer no serious barrier to penetration.

Information gained in laboratory experiments on the loss and gain of moisture by wool is being used in an examination of the efficiency of dryers employed for loose wool after scouring, after back-washing, and in cloth finishing. Observations suggest that if air can be made to flow reasonably uniformly through a mass of wool it should be possible to increase the efficiency of drying and the control of regain while greatly reducing the heat consumption. A further application of the data is being made in developing methods for estimating moisture in wool samples taken from bales by " core-boring ". There is no entirely satisfactory commercial equipment available for this purpose, and the need is likely to become urgent in Australia with the establishment of wool testing laboratories. In one new method now being examined hot air is blown through a sample which is weighed while in the drying apparatus. In another method the electrical capacity of a sample of wool is measured at two different frequencies. The value so obtained is not affected by the weight of wool tested or by the density of packing between the electrodes.

(*d*) *Friction.*—Studies of the hot spots resulting from the rubbing of steel on glass have shown, contrary to previous findings, that the rate of temperature rise is independent of the load and the velocity of rubbing. It appears that the results reported by previous workers in this field refer to aggregates of hot spots. In these experiments the effect of the velocity of rubbing on the index of friction has been investigated for the first time. For polymers rubbed at speeds exceeding about 5 cm. per sec. the index is 1 which indicates fully plastic behaviour.

8. STRUCTURE OF THE WOOL FIBRE.

(Wool Textile Research Laboratories.)

(*a*) *Direct Examination of the Fibre.*—Some insight into the variation in permeability of different regions of the fibre has been obtained by noting the penetration of lithium bromide solution into snippets of wool. The diffusion takes place more rapidly in a radial direction, but there is evidence of equally rapid diffusion in the axial direction in the cuticle.

An important extension of knowledge about the structure of wool beyond the level of magnification obtainable with the optical microscope has been made possible by applying the newly developed thin-sectioning technique to wool and hair fibres and follicles, since this permits their examination under the electron microscope. Thin sections cut from skin at a level below the zone of keratinization in the hair follicle show not only the structure of the nucleus in detail and of the cortical cell membranes, but also the structure of the fibrils and their constituent microfibrils. Previously these had been seen only in fibre fragments released by chemical and mechanical means. At the highest magnification the microfibrils are seen to be arranged in laminae and may be attached together laterally to give the sheets of microfibrils sometimes detected in wool dispersions.

The glassy layer of the hair follicle which adjoins the outer root sheath has been shown, with the aid of electron microscopy, to comprise two arrays of long fibrils of the collagen type. The sebaceous glands appear to be packed with globules and small dense mitochondria.

Knowledge of the structure of wool beyond the level of magnification that can be seen with the electron microscope is being deduced from measurements of water sorption, deuterium exchange, infra-red absorption, X-ray diffraction, and density.

The helical arrangement of amino acids proposed for proteins some years ago is consistent with the experimental results. However, the coiling of such helices into a seven-strand cable structure, as has been suggested, is not acceptable, since it yields calculated densities lower than those found by direct measurement on wool, on cortical cells fractionated from trypsin digests of wool, and on porcupine quill tips.

The location of particular chemical groups within the wool fibre is being shown in X-ray diffraction patterns of the fibre following treatment with osmium tetroxide, iodine, and mercuric acetate. It would appear that osmium and mercury are taken up in the amorphous matrix around the microfibrils.

Chemical studies reveal that the concentration of *N*-terminal residues in wool, and in a protein extracted from wool, are not significant in relation to the molecular weight of the wool proteins, and it is concluded therefore that cyclic structures are present. Measurement of the elastic properties of wool, following chemical treatments to break the various sulphur bonds, suggests that these cyclic units, of molecular weight approximating 9000, may consist of two-strand cables forming molecules about 60 Å long which are joined longitudinally by disulphide bonds.

(*b*) *Examination of Extracted Proteins.*—Supercontraction of wool by heating at 96° C. in 9M LiCl trebles the quantity of protein extractable under standard conditions with 0.1M potassium thioglycollate initially at pH 10.5. The protein component obtained from normal wool by fractional extraction with alkaline thioglycollate and stabilized by conversion to *S*-carboxymethyl kerateine 2 (SCMK2) by reaction with iodoacetic acid has been further purified by fractional precipitation with either zinc acetate or ammonium sulphate. Using radio-active zinc the binding of this metal by the protein precipitated from SCMK2 has been shown to be readily reversible.

One of the most conspicuous properties of the wool proteins examined, whether extracted with alkaline thioglycollate as in the preparation of SCMK2 or with ammonia following peracetic acid oxidation, is their pronounced tendency to aggregate reversibly. This property is responsible for the heterogeneous patterns appearing on ultracentrifugation and during electrophoresis unless special precautions are taken, for changes in viscosity and apparent molecular weight during storage, and for variations in the value found for the molecular weight according to the measuring technique used. The same intermolecular forces which cause aggregation in the laboratory are probably also largely responsible for the synthesis of wool in the wool follicle and for an appreciable share of the mechanical strength of the fully keratinized fibre.

9. WOOL PROTEIN CHEMISTRY.

(Wool Textile Research Laboratories.)

(*a*) *Studies on the Wool Fibre.*—A reagent containing copper sulphate, ammonia, and sodium sulphite, formerly used for estimating cystine and cysteine, has been found to split the disulphide bonds in wool and take about 80 per cent. of the wool proteins into solution in the form of *S*-sulphokerateine. The chemistry of this product is being investigated. The same reagent provides a ready means of introducing radio-active sulphur into wool and it can be used to form mixed disulphides.

The thioether groups formed by reaction of the cysteine residues in reduced wool with iodoacetic acid or iodoacetamide, and those of lanthionine residues, are readily oxidized to sulphoxide and sulphone groups. On hydrolysis these yield disulphide compounds, which can cause serious errors in cystine analyses.

The effect of a range of cations and anions on the supercontraction of wool has been related to their position in the lyotropic series, the small highly hydrated cations such as lithium being adsorbed least readily, and the large less hydrated anions such as iodide being strongly adsorbed. Thus, by increasing the negative charge on the wool fibre proteins, lithium iodide for example would promote disaggregation and disordering of the wool proteins and thereby increase the tendency of the fibre to supercontract.

(*b*) *Studies with Model Compounds.*—By replacing the hydrogen atom attached to the carbon atom occupying the β position in relation to the disulphide bond with a methyl group, the resistance of the disulphide bond to hydrolysis with alkali is greatly increased. On the basis of this observation two mechanisms proposed by other workers to explain the splitting of disulphide bonds in proteins with alkali have been rejected, and a third mechanism involving ionization of the hydrogen atom attached to the β carbon atom (the α hydrogen atom of the amino acid) is supported. The observation also suggests a means whereby the disulphide bonds in wool may be strengthened.

10. PROTEIN STRUCTURE.

(Division of Industrial Chemistry.)

As part of the programme of synthesizing crystallizable peptides for X-ray examination, a study has been made of the various problems associated with peptide synthesis.

X-ray studies of peptides, the units of which proteins are composed, have been continued. The main difficulties in this work are to locate peptides whose analysis is of sufficient general significance and to obtain suitable heavy-atom derivatives in single crystals sufficiently large for X-ray analysis. Suitable single crystals of a hydroxyproline derivative have been found, and the analysis of the structure has been started. A preliminary study has been made of an iodine derivative of evolidine, a cyclic peptide occurring in *Evodia xanthoxyloides.* The final stages of the analysis of DL-aspartic acid hydrochloride have been carried out, with particular attention to the elimination of errors due to thermal motion of the atoms. The extensive computation required, some of which had to be performed on an automatic computer, underlines the need for the computing machines at present being built in the Section.

Electron microscopic studies of proteins have been continued, and the examination of the ultra-thin sections of spleen has thrown some light on the way in which the iron from effete red blood cells is recovered and stored.

11. GENERAL PROTEIN INVESTIGATIONS.

(Wool Textile Research Laboratories.)

Studies of the composition of various extracts of foetal sheepskin, prepared after incubating the skin with radio-active glycine with and without prior enzyme treatment, have suggested that ribonucleic acid rather than deoxyribonucleic acid is associated with the synthesis of the major skin protein, collagen.

Evidence has been obtained that the penultimate C terminal amino acid residue in the protein lysozyme is arginine and not asparagine as reported from another laboratory.

12. BIOLOGICAL DEGRADATION OF CELLULOSE.

(Wool Textile Research Laboratories.)

To prepare substrates for studies of the enzymes of the cellulose-digesting mould *Stachybotrys atra,* a method was developed for separating glucose polymers of various sizes by elution from charcoal columns.

Observations on the β-glucoside splitting enzymes of the mould *S. atra* have been correlated with current theories of enzyme action to provide mechanism for the action of carbohydrases in general.

Extracts from the ground-up tissues of termites, representing two different species, have been shown to be capable of digesting both cellulose and chitin, the former at the more rapid rate. It is possible therefore that the termites may derive portion of their nitrogen requirements from fungal chitin.

XVII. INDUSTRIAL CHEMISTRY.

1. General.

The Division of Industrial Chemistry represents the major concentration of chemical research within the Organization, although much chemical work is undertaken in other Divisions and Sections.

This Division was formed: (*a*) to promote greater technical efficiency in established industries; (*b*) to stimulate the establishment of new industries; (*c*) to encourage the use of raw materials of Australian origin; (*d*) to seek substitutes for imported materials; and (*e*) to find uses for by-products not utilized. Latterly a further aim has been added: (*f*) to study such national problems as water conservation and bushfire control, to which the Division can contribute by virtue of its experience in other fields.

The main activities within the Division deal with minerals utilization, cement, ceramics and refractories, organic chemicals, wool, brown coal, and water conservation. There is in addition a wide programme of basic chemical work.

The Division's study of the constituents of wool wax and possible ways of utilizing them or their derivatives is described in Chapter XVI., Section 4. The Division is also studying the structure of proteins in relation to wool (*see* Chapter XVI., Section 10). The Division's work on the utilization of brown coal is described in Chapter XIX., Section 5.

Division of Industrial Chemistry.—This year has brought further justification of the policy of devoting a substantial part of the Division's programme to basic studies. In the last Annual Report special attention was drawn to four projects each of which had led to successes in directions which could not have been foreseen when the work was first planned. One of these, the Mansfield process, for reducing evaporation on water storage, which arose directly from fundamental studies of surface phenomena, is now finding wide application on small farm dams, and, in a modified form, has been shown to be effective in moderately large reservoirs. It is pertinent to point out that the work on evaporation control was mostly done at a time when Australia was enjoying good seasons of widespread rainfall and when evaporation control in Australia could not have been regarded as a matter of immediate urgency. By the autumn of this year, however, with the country again threatened by drought, the programme has found spectacular justification. Had the research started when the need was immediate, no solution could have been found in time.

The success of the Divisions' zirconium-hafnium processes demonstrates a further important practical application of basic research. The study of the chemistry of Australia's beach sands was started in the Division several years before the need was apparent to separate hafnium from zirconium for use in certain types of atomic reactors. As the result of this fundamental research, when the necessity arose, the metallurgical techniques were available to accomplish the purification of zirconium. The new process, it is expected, will now play a vital part in the technology of atomic energy production.

Other examples of this nature could be quoted, but the Mansfield process and the zirconium-hafnium separation adequately emphasize that it is imperative that a proportion of the work of the Division should be aimed at finding solutions for the problems of to-morrow.

It is gratifying to record that royalties from the inventions originating in the Division have been substantially increased during the year. The purchase by the National Distillers and Chemical Corporation, United States of America, of rights under the Organization's hafnium-zirconium patents (see Chapter I., Section 10), will represent the most profitable patent licensing agreement so far transacted by the Organization. With the revenue received from royalties on the Division's multiple monochromator which is being manufactured under licence by the Perkin-Elmer Corporation, United States of America, now totalling 60,000 dollars, these two inventions alone are returning an appreciable income to the Commonwealth.

The Division continues to develop co-operative investigations with various branches of industry, both in Australia and overseas. It is a pleasure to acknowledge that Smith, Kline, and French Laboratories of Philadelphia, United States of America, with whom the Division is collaborating in the systematic pharmacological screening of Australian and New Guinea plants, have made a donation of £1,000 towards the cost of collecting the necessary plant materials. However, the number of plants which have so far been classified as warranting more detailed examination is such that additional research staff is required. To make this additional staff available, Smith, Kline, and French Laboratories are providing an annual grant to the Division of £6,000 for a minimum period of three years.

A fruitful collaboration has also continued with the four major copper producers of Australia in an investigation of the fluid bed roasting of copper concentrates and the recovery of copper from the calcines by leaching and electrowinning.

In the last report it was pointed out that the ratio of salary expenditure to equipment expenditure had fallen alarmingly in the last decade. The funds available in the current year have shown no significant change in this ratio, and the consequent cumulative decline in the Division's equipment and research facilities continues. This is a matter of concern, and inevitably means that increasing effort, which is quite uneconomic, must continually be expended in bringing obsolete equipment up to date, at the expense of effort normally available for the research programme.

Several officers of the Division have continued to take their places in the committees and commissions associated with the International Union of Pure and Applied Chemistry (I.U.P.A.C.). The Chief of the Division has continued to serve as the Convenor of the affiliated National Committee, an office in which he is being succeeded by Dr. A. L. G. Rees. Dr. Rees is also a member of the I.U.P.A.C. commission on physico-chemical data and standards; Dr. S. D. Hamann is a member of the subcommission on the thermodynamic properties of fluids; and Dr. A. Walkley represents Australia as the national secretary of the International Committee for Electrochemical Thermodynamics and Kinetics. Mr. J. P. Shelton attended the Fifteenth Congress of the Union of Pure and Applied Chemistry as Australian delegate, and was chairman of a session on optical methods.

The international status of other officers has been recognized by invitations to take part in conferences overseas. Dr. K. L. Sutherland acted as a session chairman at the Second International Congress of Surface Activity held in London in April. During the tenure of his Commonwealth Fund Fellowship, Dr. J. D. Morrison was an invited contributor both to the A.S.T.M. Conference on Mass Spectrometry and to a meeting of the American Physical Society. Other officers who have attended overseas conferences by invitation are Dr. W. O. Williamson, the Ceramics Division of the M.I.T. summer conference, Dr. M. E. Winfield, the International Congress on Catalysis in Philadelphia, and Mr. R. C. Croft, the Third Conference on Carbon at Buffalo.

2. Minerals Utilization.

(Division of Industrial Chemistry.)

Research concerning the extractive metallurgy of certain of the less common elements continued to form a substantial part of the Section's programme. In this category is included the work on the recovery and purification of zirconium, hafnium, thorium, uranium, and germanium from Australian minerals and raw materials. This emphasis has been amply justified by the adoption by an American industrial organization of the new process devised for the separation of hafnium from zirconium by a member of the Section.

The investigations concerned with the electrowinning of copper, which are sponsored by the four major copper producers of Australia, serve to stress the increasing trend towards hydrometallurgical procedures in many fields quite unrelated to the less common elements.

These applied aspects of the Section's programme are balanced against such projects as those concerned with the chemical and physical characterization of new chalcogenide compounds and with the manifold aspects of graphite chemistry which are ordinarily classed as fundamental research. It is increasingly evident, however, that this distinction is quite arbitrary because a full assessment of the properties of any mineral, or its derivatives, is an essential preliminary stage in its potential utilization by industry.

(*a*) *Hydrometallurgy of Copper.*—The investigation on electrowinning of copper from calcined chalcopyrite from a fluo-solids reactor has now passed from the exploratory stage to the examination of specific conditions of operation and to the stage of direct planning of semi-pilot-plant experiments. To assist further in the project, the companies sponsoring this work provided the means for an officer to visit the principal copper mines of central Africa, where much useful information was gathered on current metallurgical practice. The choice of a suitable calcine from among those offered by the Chemical Engineering Section has been narrowed down, and detailed experiments have been completed to determine the optimum temperature, time, and acid concentration to give the maximum copper extraction and the minimum extraction of iron, molybdenum, and arsenic. The extent to which these impurities build up in a cyclic process and the effect of continuous leaching, as opposed to batch leaching, have been determined. The residual copper which causes increases in cyanide consumption in subsequent gold recovery has also been examined, but its exact nature has yet to be elucidated. The relation between the amounts of impurities in the cathode with the amounts in the electrolyte has been studied with the object of fixing permissible tolerances. A small pilot plant has been erected for continuous leaching and for the continuous production of cathode copper in kilogram quantities. To enable all stages of the process to be followed and the products assessed, rapid methods of analysis, mainly polarographic, are being developed. The Metallurgy School of Melbourne University has agreed to melt the cathodes produced and draw wires from them for tests of ductility and conductivity, the ultimate criteria of a satisfactory product.

(*b*) *Uranium Extraction.*—In the field of autogenous pressure leaching, detailed kinetic studies have now been made on the oxidation of uraninite, pyrite, chalcopyrite, and chalcocite, under acid conditions. Further improvements have been made in reactor design, notably with respect to temperature control and sampling during the course of a digestion. Attention is also being given to the application of pressure leaching to the extraction, not only of uranium but also of valuable base metals, from ores or materials which exhibit relatively poor response to the more conventional extraction procedures. The scope of the project is thus being gradually widened to allow improved techniques to be applied under acid or alkaline conditions, with or without oxidation as an essential feature.

The recovery of uranium by solvent extraction has been further investigated with tributyl phosphate as the extractant with nitrate leach liquors, and alkyl phosphoric acids or amines with sulphate liquors. Parallel studies on the extraction of phosphoric acids by these reagents have also been made, with a view to improving the grade of the final product. Work on the regeneration of nitric acid, both by solvent extraction and by electrolysis using an ion-exchange membrane cell, has been continued.

Considerable analytical service has been provided for various external bodies as well as for the pilot-plant investigation of the jigged-bed process. Co-operation with the Australian Atomic Energy Commission and Territory Enterprises Proprietary Limited has been continued, especially with regard to the testing of new ores and the investigation of specific problems arising on the production scale.

(*c*) *Zirconium and Hafnium Chemistry.*—The chemical separation of the small amount of hafnium which invariably accompanies zirconium in the mineral zircon, and other zirconium ores, is a matter of considerable difficulty. It is an essential step in the use of zirconium metal as a cladding element for uranium rods in certain types of nuclear reactors. Previous reports in this series have outlined the progress of a new and improved process for effecting this separation based on selective sublimation after differential reduction of the anhydrous chlorides of zirconium and hafnium. This work reached a very satisfactory conclusion during a visit abroad by the officer responsible for the process when the overseas rights of the patented method were sold to National Distillers Products Corporation of United States of America. This company has set up a pilot-plant equipment to produce hafnium-free zirconium chloride by the C.S.I.R.O. process at its U.S.I. Chemicals Research Division at Cincinnati.

For many industrial purposes the removal of hafnium from zirconium compounds is not necessary. In such instances the cost of the product devolves to a large extent on the difficulty of decomposing the chief ore, zircon, which ordinarily requires high-temperature fusion processes. Recent investigations have indicated that it may be possible to convert zircon to water-soluble zirconium compounds at low temperatures by a new process. A co-operative investigation with an Australian chemical company has been begun to check the industrial significance of the laboratory results.

A fundamental study of the thermodynamic properties of the lower chlorides of zirconium has been made possible by the development of a new process for preparing pure zirconium trichloride.

(*d*) *Thorium Purification.*—Studies of the van Arkel-de Boer iodide process for the preparation of high-purity metallic thorium have been continued. Many improvements in technique and performance have been made particularly with regard to the role of impurities in the process.

(*e*) *Germanium Survey and Extraction.*—A survey of the occurrence of germanium in flue dusts and related materials derived from Australian coals was completed and the results were published.

Work on the industrial extraction of germanium from flue dusts of certain coal-burning power stations was continued. As this material contains only about 1 lb. of germanium metal per ton the investigation was mainly restricted to simple procedures and low-cost reagents. Hydrometallurgical processes combined with some degree of mechanical beneficiation have been employed. In general it has been found that the germanium appears to be present in two states of combination in the dust. One form responds readily to various types of hydrometallurgical extraction but the other form, which is usually the lesser fraction, remains comparatively insoluble at low reagent concentration.

(*f*) *Graphite Chemistry.*—Studies on molecular compound formation by graphite were continued and intercalation of metal-organic substances in graphite has been found possible. This notable extension of previous work has opened up new and useful fields of investigation.

Examination of paraffin-soluble metal-organic compounds as additives for suppressing the smoking of hydrocarbon fuels was continued. The substances chosen were selected in accordance with theories derived from earlier studies on graphite compounds. Marked success has attended the use of iron tris-acetylacetonate particularly in conjunction with acetylacetone. This combination has been shown to be very effective as a carbon suppressant when used in jet engines, oil-fired furnaces, or internal combustion engines of both petrol and diesel types. This work forms the basis of patent applications in Australia and overseas.

(*g*) *Phototropic Compounds.*—Investigations on the causes of light sensitivity of certain metallic oxides, such as titanium oxide, have been concluded, and the results have been published.

(*h*) *Transition Group Sulphides, &c.*—Work was continued on the synthesis and examination of some 50 different compounds. These represent the phases present in the twelve systems of binary combinations of titanium, zirconium, hafnium, and thorium with the chalcogenide elements sulphur, selenium, and tellurium. All these preparations have been shown by X-ray analysis to be distinct phases. Each has been examined for specific resistivity, type of conduction (metallic, p- or n-type semi-conduction), magnitude of thermo-e.m.f, and rectification, as well as such physical properties as density and graphitic structure. Several of the properties, especially the specific resistivity, demonstrate remarkably clearly the gradual transition from semi-metallic to metallic affinities of the compounds from titanium through to thorium. The relative chemical stability of the compounds to a wide range of reagents has also been determined. Many of these chalcogenides have not previously been described, and in other instances the degree of purity attained exceeds that hitherto achieved with the result that the intrinsic properties have been found to diverge somewhat from the hitherto accepted values.

(*i*) *Chemical Crystallography.*—Chemical crystallographic studies which had previously been concentrated on defective oxide systems have now been directed towards the chalcogenide systems described in the preceding paragraph. A number of new interesting problems in the crystal chemistry of non-stoichiometric solids have been thereby defined. Preliminary single crystal studies of the trichalcogenides AX_3 have been made, and the structure analysis of $ZrTe_3$, a representative member of this group, was begun. It has been found that the sesquisulphides of the supposedly isomorphous metals hafnium and zirconium exhibit gross differences of structure. Several other systems with the approximate A_2X_3 formula have been found to show wide ranges of composition within a single phase region. The structure of one of these, Ti_2S_3, has been determined by X-ray analysis. In much of this work only powder diffraction techniques can be used and conventional Debye-Scherrer cameras are often inadequate. Accordingly a Hägg focusing powder camera was constructed which gives precision determination of lattice parameters of even the most oblique systems.

(*j*) *Special Techniques.*—Further developments were made in the techniques of generating and handling the highly reactive element fluorine, and studies on the fluorides and oxyfluorides of cerium were continued.

A modern radiochemical laboratory was designed and equipped for use in handling radioactive isotopes and similar materials. The preparation of high-purity metallic thorium was much facilitated by the means of assessment thus afforded.

3. CEMENT AND CERAMICS.

(Division of Industrial Chemistry.)

The activities of this Section are mainly concerned, on the one hand, with the manufacture of cement and its utilization in concrete, and on the other, the occurrence, properties, and utilization of ceramic and refractory materials.

(*a*) *Cement Hydration and Strength Development.*—A new method for estimating the rate of hydration of cements has shown that, in general, as much as one-third of the cement contained in a mixture may be converted to hydration products before any measurable strength is developed. An attempt is therefore being made to determine whether this fraction of cements, which does not appear to contribute to the cementing process, can be reduced without any loss for final strength.

Systems of very low water content and minimum void space were selected as being likely to show maximum efficiency. Although high strengths were obtained at an early stage in such systems, the hydration data indicated that the gains could not be maintained at the initial rates because material transfer is hampered at such limited water contents.

The effects of alkali on the strengths developed by cement pastes have been investigated to some extent, but the problem has proved complex. Compressive strength appears to be affected adversely by alkali additions above the normal range, although modulus of rupture values may be increased by such additions.

(*b*) *Concrete Additives.*—The results of the work on air entrainment in cement pastes have confirmed the view that this technique may have little value in placing concretes unless use is made of certain specific types of surface-active agents which entrain air and promote the attachment of air bubbles to the cement particles; agents which merely entrap air are relatively ineffective.

Continuation of earlier work on the effects of organic additives to concrete prior to hardening has revealed that " Krilium ", a soil-conditioning agent, produces markedly beneficial results. In large-scale trials the material has shown some promise in the manufacture of certain concrete products, where benefits have included reduction in aggregate segregation and improvement in the plastic and bleeding characteristics of mixes.

(*c*) *Concrete Durability.*—A novel method of increasing the resistance of concrete products to attack by sulphate solutions has been evolved in the course of a project designed to overcome the problem of providing large quantities of pipes for the drainage of irrigation areas in parts of Australia characterized by ground-water sulphates. The method consists in curing the concrete in a special atmosphere after final set has occurred.

The success of treatments designed to prevent plant growth in hydro-electric power station supply races has been demonstrated by field trials. Moss growth, which had previously restricted the supply of water to the turbines of one station by 10 per cent., has been kept down to negligible proportions over the past two years by incorporating elemental sulphur or certain copper compounds in the race concrete and sodium silicate surface layer. These added materials are toxic to moss but are insoluble in water and therefore do not cause any pollution of the water supply.

(*d*) *Cement Kiln Refractories.*—The completion of phase equilibrium studies on the reaction of cement clinker with basic refractory lining materials has been followed by an investigation of the physical factors affecting the performance of chrome-magnesite lining bricks. Results to date indicate that the performance of this type of refractory can be more seriously affected by slight variations in the mechanical details of fabrication than by changes in composition.

(*e*) *General Refractories.*—Typical Australian-made siliceous and aluminous refractories have been examined in regard to resistance to spalling and to attack by brown coal ash at high temperatures. The performance of highly aluminous bricks is superior to that of more siliceous varieties in both these respects.

Attempts to fabricate shapes from refractory raw materials by pressing at high temperatures have shown some encouraging results. Bauxite and sillimanite compacts of high density have been produced, but cracking due to thermal shock subsequent to pressing has proved to be a major problem.

The investigation of reaction conditions in the linings of copper-melting furnaces by phase equilibrium studies of the copper-silica-oxygen system has been held up whilst extensive modifications have been made to the apparatus. These modifications have been designed to permit operation of the normal quench technique in strictly controlled atmospheres at low oxygen partial pressures.

(*f*) *Special Ceramics and Cermets.*—Further improvements have been made in techniques for casting and firing refractory magnesia ware. The non-aqueous slip-casting technique developed for magnesia has been successfully applied to the production of calcium oxide ware.

The current programme on special ceramics includes attempts to stabilize limeware against hydration and the development of new methods for the stabilization of zirconia. The latter project is being carried out in collaboration with the Minerals Utilization Section.

In the investigations on cermets, which are metal-bonded ceramics, some advances have been made in improving the dispersion of the metal phase. The systems studied were chromium-bonded alumina and titanium carbide compacted with a nickel-based alloy.

(*g*) *Ceramic Whiteware.*—Australian clays and ceramic raw materials have been combined in experimental bodies designed for the production of earthenware and ovenware. A project carried out in collaboration with a British tableware firm has shown that articles of good quality can be manufactured from a body based on Victorian clays.

A formulation has been developed which overcomes the lack of a satisfactory crimson glaze for hard-fired earthenware. Faults in the manufacture of wall tiles, artware, and decorated porcelain have been investigated and solutions proposed.

(*h*) *Clay Investigations.*—Fundamental studies have shown, in more detail, the similarities and distinctions that exist between vermiculites and the type minerals which characterize bentonite clays.

Bentonites from new deposits in Victoria and New South Wales have been examined, in the hope of finding a local material to supplant current imports. The quality and potential extent of the New South Wales deposit could be sufficient to accomplish this object.

In Adelaide members of the Section continued investigations on raw materials for the brick and pottery industry of South Australia, with support from the State authorities. An extensive account of the general properties of brick clays in the Adelaide area has been completed, in which the need for blending clays to conserve limited deposits is stressed, and the relevant production factors are discussed.

4. FOUNDRY SANDS.

(Division of Industrial Chemistry.)

A laboratory, located in the Metallurgy Department of the Royal Melbourne Technical College, is equipped for the study of foundry problems with special reference to moulding sands. A catalogue of Australian moulding sand deposits is maintained, and whenever a new source of sand becomes available it is evaluated for its particular usefulness in the foundry industry.

The Section has recently undertaken a study of the expansion of moulding sands which results in the familiar defects in castings known as "buckle and scab". A method of simulating the conditions which cause these defects is being developed as a first step in studying the variables which might be used to control them.

In the Sydney district the need for suitable fine free sands has been accentuated by the recent trend to core moulding of small articles. The Section is investigating special methods of separating the finer fractions from building and other sands.

5. PHYSICAL CHEMISTRY.

(Division of Industrial Chemistry.)

During this year laboratory work has commenced on three new problems: some aspects of the fighting of bush fires, nucleation of clouds, and the separation of the components of tars from the Lurgi process for gasification of brown coal. The work on separation of uranium from slurries and the reduction of evaporation of water have maintained their high priority because of the prospects of successful application. Basic research continues on the effect of high pressure on chemical reactions, the properties of liquid mixtures as determined by their molecular structure, the chemical properties of carbons, and the biological use of gaseous nitrogen.

(*a*) *Conservation of Water.*—After further successful trials on small storages, the conditions required for most useful operation of the technique of using cetyl alcohol enclosed in floating rafts to reduce evaporation were formulated as specifications. Suitable cetyl alcohol and containers are now available commercially.

A satisfactory trial of an alternative method of spreading and maintaining on large areas a monomolecular film of cetyl alcohol was carried out during the 1956-57 summer season on a reservoir approaching 1,000 acres in area. In this experiment, conducted in co-operation with the Broken Hill Water Board, drops of a solution of cetyl alcohol in a volatile solvent were dispensed upon the water surface and over a period of 14 weeks evaporation was reduced by 37 per cent.

Work aimed at developing other techniques of spreading the monomolecular films, and of improving the present methods, is continuing.

Further study of the influence of the film on transfer of oxygen shows that there is no effect in the absence of wind, but transfer is reduced by 40 per cent. under windy conditions. This reduction does not of course bring the transfer rate below that obtaining in still conditions, so that it is not significant in practice.

(*b*) *An Ion-exchange Process for the Recovery of Uranium from Ore Slurries.*—This process, described in the Annual Report for 1956, effects recovery of uranium on an ion-exchange resin with unfiltered pulps obtained by leaching an ore with acid. The process has been applied on a pilot scale to ore from the Mary Kathleen Mine, Queensland, and it was demonstrated that, compared with a conventional process, the capital cost of a plant treating 1,000 tons of ore per day by the new process would be £625,000 less, while the annual operating savings would be £75,000. The process allows conventional thickeners and filters to be replaced by a small cyclone desanding unit, and this leads to the main part of the savings which the method makes possible.

A joint development programme with Territory Enterprises Proprietary Limited and the Australian Atomic Energy Commission has commenced on the application of the process to an Australian uranium ore body not amenable to conventional treatment.

The process is being tested by two manufacturers of chemical plant for the treatment of gold-bearing ores.

(*c*) *Tar from Brown Coal.*—As soon as supplies of tar were available from the Lurgi brown coal gasification plant of the Gas and Fuel Corporation of Victoria, an investigation was started on its constituents. Methods including distillation, adsorption, solvent extraction, and gas chromatography are being used to separate and identify the important constituents, particularly the hydrocarbons and phenols. This work is being carried out in collaboration with the Gas and Fuel Corporation and the Organic Chemistry Section of this Division.

(*d*) *Properties of Liquids.*—Improved equipment has been used to measure the technically important thermodynamic properties of liquids and solutions. Further development of the " correlation " theory of liquids has given fundamental insight into the process of solid melting to liquid, and will enable predictions of properties of solutions to be made. New measurements have been made on solutions of alcohols in benzene and solutions containing acetone and other polar liquids. A wider study of the effect of changing temperature on thermodynamic properties is in progress.

(*e*) *Chemical Effects of High Pressure.*—The effects of pressure on the rates and equilibria of chemical reactions in liquids are proving valuable in testing the theories of reactions in highly compressed systems and in predicting the kinds of reactions which may be favoured by an increase in pressure. Simple reactions involving ions or free radicals have been studied, and some attempt has been made to follow polymerizations at high pressure. Until recently, the measurements have been limited to an extreme pressure of 45,000 atmospheres, where an acceleration of 2,000-fold was found for one reaction. It is planned to extend the pressure range beyond 100,000 atmospheres by making use of the dynamic pressures produced in explosions.

(*f*) *The Chemistry of Carbon.*—Carbon is produced by incompletely burning a number of natural fuels. The products vary widely in usefulness, so that a study of the nature of the functional groups in activated carbons and carbon blacks has been made particularly with reference to the desalination of brackish water and the reinforcement of rubber. The acidity of sugar carbons activated at temperatures in the region of 400-600° C. and of ink and channel blacks has been shown to be due to phenolic hydroxyl groups as in the phthalein and fluorescein dyes. Quinone structures are formed in these carbons under alkaline conditions, and these account for the copolymerization of these carbons with rubber. Sugar carbons activated at 800° C., and also furnace blacks, contain chromene structures which are readily oxidized to carbonium ions by molecular oxygen in the presence of acid. The chromenes account for the ability of these carbons to copolymerize with rubber and for the phenomenon of " scorching ". Quinone groups have also been identified in such activated carbons. The chromene-carbonium ion and the quinone-hydroquinone couples of these carbons can account for their electrochemical and catalytic properties.

The study has demonstrated the feasibility of preparing novel ion- and electron-exchange adsorbents with functional groups capable of direct electrical regeneration.

(*g*) *Nitrogen Fixation.*—In the fixation of atmospheric nitrogen by root nodules and by certain soil bacteria, nitrogen is taken up by the enzyme nitrogenase and is then converted to ammonia. Nitrogenase is considered to be a modified form of hydrogenase, the enzyme which takes up or evolves hydrogen gas; attention has therefore been given to the purification and properties of hydrogenase. The most highly purified preparation to date absorbs light at $450 \mathrm{m}\mu$, which, in harmony with tracer experiments, supports earlier proposals that hydrogenase is an iron enzyme.

Among the synthetic systems with hydrogenase-like properties is a solution of cobalt cyanide. This can take up hydrogen reversibly, and can also decompose water to yield hydrogen gas; the hydrogen evolution is strongly accelerated by caesium ions and by minute quantities of the dyestuff methyl viologen. Investigation of the nature of the reaction suggests that it may be possible to prepare an aqueous mixture of metal complexes which, like the nitrogen-fixing system of bacteria, evolves hydrogen in the absence of nitrogen but evolves ammonia when nitrogen is present.

(*h*) *Nucleation to Form Ice.*—Work on the action of silver iodide in causing cold water droplets to form ice has been undertaken as an extension of the rain-making programme of the Division of Radiophysics. The immediate practical problem is the failure of the silver iodide particles to act as freezing nuclei after a short exposure to atmospheric conditions. Present laboratory methods were considered to be insufficiently accurate for counting of freezing nuclei discharged into a laboratory cold chamber. A new method has been devised which provides an accurate count by allowing the small ice crystals which have formed to fall on to a moving belt wetted with supercooled sugar solution. Each ice crystal then continues to grow and in a short time becomes large enough to be counted easily by eye.

(*i*) *Fire Research.*—Following a comprehensive survey of bushfire problems, research has been initiated on several promising aspects. Among the attempts to increase the safety and comfort and thus the efficiency of fire-fighters, a cream has been developed which reflects much of the heat falling on exposed skin.

The forestry fire-fighting organizations have suggested several urgent mechanical problems such as the wear of pumps and the design of spray nozzles. The investigation has yielded some promising developments which are now to be subjected to field trials.

The possibilities are being considered whereby trees can be cheaply fireproofed either before or during fires. By this means small ground fires, including " burning off ", may be restricted and damage avoided to a forest.

One of the basic needs of this research is detailed data on the conditions within a bushfire. Temperature of the flames, wind velocity, rate of spread, nature of fuel, as well as the usual local meteorological data are needed before much can be known of the conditions under which fires become dangerous. For this purpose special apparatus for field measurements is being developed.

A number of the forestry services expose small billets of wood in a forest; from the weight of these and from the weather forecast a fire danger rating is determined. A critical survey has been made of this method.

(*j*) *Miscellaneous.*—A British Memorial Foundation Fellow has joined the Section for the purpose of measuring the electrical conductivity of water at high pressures and temperatures. This work has a bearing on the mechanism of corrosion in boilers.

A study is being made, in collaboration with the Australian Aluminium Production Commission, of the chemistry of pitch in an endeavour to obtain a better understanding of its binding properties for the formation of carbon electrodes in the electrolytic process of aluminium production.

The work on the properties of polyelectrolytes has been terminated. There has been some development of the apparatus for the measurement of activities in solutions at high dilution as an alternative to the electromotive force method.

A theoretical study of the influence of electric charges on coalescence of drops shows that, provided they approach sufficiently closely, coalescence is assisted by the electric charges even when the signs are the same.

6. Chemical Physics.

(Division of Industrial Chemistry.)

Work has continued along four main lines, namely, (a) protein structure investigations, (b) the chemical physics of the solid state, (c) the determination of molecular structure and energetics, and (d) the development of new instruments and techniques. Considerable collaborative and service work, based on the application of the specialized instruments and techniques developed in the Section, has been undertaken for industry, universities, and other parts of the Organization. Several guest workers have been accommodated for various periods during the year, both for purposes of collaboration with officers of the Section and for training in the use of specialized techniques. A major service was provided by the Section in the installation of an electron miscroscope at the Australian National University, Canberra, and in the training of an electron microscopist to operate and maintain it.

Grateful acknowledgment is again made to Professor N. S. Bayliss for providing accommodation and supervision for the vacuum ultraviolet and certain aspects of atomic absorption spectroscopic work.

Further progress has been made in encouraging the manufacture of scientific instruments in Australia, and a commercial firm is now producing high-stability power supplies to a design developed in the Section. Royalties for the use of the multi-pass system in a commercial infrared spectrometer are still being paid by an overseas manufacturer. Patent coverage has been sought this year for three more instruments developed in the Section.

(*a*) *Protein Structure.*—This work is described in Chapter XVI., Section 10.

(*b*) *Chemical Physics of the Solid State.*—The theoretical and experimental study of defects in crystals and of their implications in determining the physical and chemical properties of solids has continued.

Theoretical work on the aggregation of *F*-centres in ionic solids has been concluded, and the results for sodium iodide and potassium chloride show that it is energetically possible for *F*-centre aggregates to form nuclei for the growth of metallic specks. These results have particular bearing on the general problem of solid state reactions, in which the most significant stage is the separation of a new phase, which follows aggregation of defects.

Work has proceeded on the study of the mechanisms of oxidation of solid and molten zinc, and difficulties encountered in measurement of low-temperature oxidation rates have been overcome by the development of an absolute capacity differential micromanometer. An automatic needle-valve of novel design for controlling gas-flow rates has been developed and a patent applied for. Its performance is far superior to that of commercially available valves of this type.

Theoretical work on hypothetical decay mechanisms in phosphors has led to new concepts in the use of the phosphorometer, and has greatly simplified the analysis of the results obtained with this instrument.

Work on the photoconductivity of cadmium sulphide has led to the development of a new principle of operation of Pirani-type gauges and to the invention of a curve-follower of simple design, for which a patent has been sought. This instrument controls an electrical parameter so that its value with respect to time follows the same functional form as a given curve drawn on paper.

Development of special-purpose electronic circuits for use in the study of defect solids has continued. One such circuit has been applied to the construction of a stabilized voltage source, which is now being produced commercially under the name " Stacpac ".

(*c*) *Molecular Structure Studies.*—The determination of molecular structure and energy states of molecules, which is of fundamental importance to much of chemistry and biology, forms a major part of the Section's work.

(i) *Structure Analysis by X-ray Diffraction Methods.*—Further work on magnesium-vermiculite has contributed valuable information on this typical clay mineral.

(ii) *Structure Analysis by Electron Diffraction Methods.*—In extending the work on the detection of hydrogen bonds by electron diffraction studies a survey has been made of a range of organic compounds, and some of the aromatic polycarboxylic acids have been found to lend themselves to investigation. Preliminary measurements have been made on trimesic acid.

(iii) *Spectroscopic Studies.*—A theoretical analysis of the molecular spectra of fluorine has led to an estimate of the dissociation energy of the fluorine molecule (37.1 kcal/mole).

In the investigation of the higher-energy states of iodine and bromine, which is being carried out by an officer located in the Chemistry Department, University of Western Australia, detailed observations have been made on the absorption of iodine on cell windows, which can lead to spurious results in the measurement of extinction coefficient.

Study of the electronic absorption and reflexion spectra of metal complexes with organic and inorganic ligands has been initiated.

(iv) *Molecular Ionization Potentials and Bond Energies.*—Appreciable improvement in electron-impact spectra has been obtained by reducing the noise level in the various components of the mass spectrometer.

(*d*) *Development of Chemico-physical Techniques.*—The development of new apparatus and new techniques is a vital part of the Section's activities, since such development often leads to a clearer understanding of physical and chemical phenomena and sometimes to instruments capable of commercial exploitation.

(i) *Electron Microscopy.*—Theoretical and experimental work on electron interference fringes has established that it is possible that crystal structures can be determined by direct electron microscopy provided that the difficulties of producing and superimposing sufficiently thin crystal layers can be overcome.

A by-product of this investigation has been the development of new approaches to the analysis of structures.

Extremely strong films for supporting electron microscope specimens without obscuration have been produced by using composite layers of plastic and evaporated carbon or silicon monoxide.

(ii) *X-ray Diffraction.*—The high-power X-ray generator has been modified to accommodate a rotating anode to overcome inordinately long exposure times. An adapter for the Weissenberg goniometer has been built to permit the recording of X-ray photographs at temperatures low enough to avoid errors due to thermal motion of the atoms. Construction of the automatic counter goniometer is proceeding satisfactorily.

(iii) *Computers.*—The image-seeking computer, which will greatly reduce the time and labour required for structure analysis by X-ray and electron diffraction methods, is almost complete.

(iv) *Development of New Techniques in Structure Analysis.*—The new formulation of physical optics described in the previous Annual Report has been extended and applied to a number of important problems. The theory of scattering of electrons by crystals has been reformulated, and the main results of the classical theory have been rederived as a check on the validity of the method. The new theory is most powerful in the range where classical methods break down, and, since this is the range corresponding to the conditions most often encountered in practice, it has been possible to derive a number of results of practical importance. The scattering of electrons by atoms has been re-investigated for the purpose of determining the factors important in crystal structure analysis and in high-resolution diffraction. Although it has not yet been found possible to construct a completely general theory which is analytically tractable for the case of partial coherence, a method has been developed which is sufficiently general to describe many of the effects encountered in high-resolution diffraction systems. A preliminary assessment has been made of the effects associated with scattering from imperfect crystals. Some problems associated with the formation of electron microscope images of crystals have been resolved. Other possible approaches to the imaging of atoms and molecules in crystals have been suggested by this theoretical development. Experimental work designed to test these possibilities is in hand.

(v) *Spectroscopy.*—The study of atomic absorption spectra as a means of chemical analysis has been continued and a relatively inexpensive atomic absorption spectrophotometer has been developed. A specialized type of non-dispersive monochromator for use in this work is under development.

New types of high-frequency electrodeless Raman sources have been developed for the study of coloured solutions and will be used in an attempt to determine the vibrational spectra of halogens in solution. The light losses in a high-speed Raman spectograph have been determined, and this information will be used in the design of a double-pass Raman spectrometer.

A simple ratio-recording system for use in double-beam spectrophotometers has been developed, which is applicable to double-beam double-pass instruments. It will be used in a double-pass ozone spectrophotometer.

A new electronic method of comparing the output of two photomultipliers has been developed and is being applied in atomic absorption spectroscopy.

All of these developments represent potential commercial scientific instruments.

(vi) *Mass Spectroscopy.*—Construction of a new electrometer and amplifier has resulted in appreciable reduction of the noise level of the mass spectrometer.

(vii) *Specialized Optics.*—Modifications have been made to the mounting of the optical components of the échelle attachment to render the instrument usable for long exposures. Progress is being made in the development of equipment for producing multi-layer evaporated films. A prototype multipath absorption cell for small absorbing volumes has been built.

(*e*) *Collaborative and Service Work.*—The specialized facilities of the Section have been made available through collaboration and service to industry, universities, and other parts of the Organization. The scope and extent of this activity is illustrated by the following selection of the more important problems undertaken.

(i) *Electron Microscopy.*—Extensive studies on the lipoprotein lamellar systems occurring in the chloroplasts, mitochondria, and endoplasmic reticulum components of plant and animal cells.

(ii) *X-ray Diffraction.*—Examination of samples of phenothiazine, of ash from special-quality papers, and of samples of margarine, and the determination of the molecular weight of β-bauerol acetate.

(iii) *Spectroscopy.*—Infra-red study of the structure of organic natural products—in particular, alkaloids of the *Senecio, Crotalaria,* and *Heliotropium* families; identification of aldehydes derived from butter taints; analysis of cresol fractions from brown-coal tar; determination of the terminal groups in activated carbons and in Australian pitches. Ultraviolet spectroscopic identification and estimation of impurities in " absolute " alcohol. Spectrochemical analysis of ash from special-quality papers, of agricultural lime samples, of fuel oil ash. Study of the interaction of hydrogen with cobalt cyanide systems. Identification and determination of α- and β-carotene and of vitamin A in canned foodstuffs.

(iv) *Mass Spectroscopy.*—Analysis of various gases such as acetylene, ethylene, nitrogen, hydrogen, and amines for trace quantities of unknown impurities. Measurement of the 160/180 ratios in the products of pinacol decomposition.

The examination of Tertiary shell fossils, a collaborative project with the National Museum of Victoria, has been completed. From the 160/180 ratios in the carbon dioxide generated from the shells the palaeotemperatures of some 200 shells representative of various geological epochs have been determined to an estimated accuracy of 1° C.

(v) *Specialized Optics.*—Study of samples of smoky crystalline quartz from Tasmania to assess their potential usefulness in the construction of optical instruments.

(*f*) *Instrument Laboratory.*—Major items completed this year include: Ratio meter for measuring the ratio of photomultiplier outputs, high-stability power supplies, hollow-cathode lamps, metal-evaporating sources, a stigmator for the electron microscope, and an ultramicrotome of novel design. The construction of an image-seeking computer is nearing completion. The method of machining accurate cylinders has been further refined.

7. ORGANIC CHEMISTRY.

(Division of Industrial Chemistry.)

The greater part of the research programme of the Organic Chemistry Section is concerned with the examination of several Australian natural sources of organic chemical materials, with a view to their wider utilization. Among those materials to which attention is currently being devoted are: Wool wax and suint, sugar-cane wax, brown-coal tars, vegetable and animal fats, and related long-chain compounds. An important part of the programme is the search for alkaloids of possible pharmaceutical value from the native flora; related topics include the examination of plants known or suspected to be poisonous to live-stock, and a study of root exudates and their possible significance to agriculture.

(*a*) *Wool Wax and Suint.*—This work is described in Chapter XVI., Section 4.

(*b*) *Sugar-cane Wax.*—The method of refining sugar-cane wax by fractionation from a solvent consisting of a mixture of light petroleum and ethanol was mentioned in the previous report. It has proved to present no great difficulties when operated on a larger scale and has been used to prepare larger quantities of the wax for further appraisal of its properties.

(*c*) *Plant Alkaloids.*—The collaborative programme with Smith, Kline, and French Laboratories of Philadelphia, United States of America, has revealed a number of species from both Australia and New Guinea of sufficient promise to warrant further examination. Additional staff, made possible by a grant from Smith, Kline, and French, are to undertake the separation of the component alkaloids from these species for chemical and pharmacological study. The Division's field botanist spent two months in the Lae-Bulolo area, collecting over 100 species and gaining experience which will be of value for future collections.

Work is continuing on the alkaloids of *Alstonia constricta,* other than reserpine, which give non-volatile acids (trimethoxybenzoic or trimethoxycinnamic) on hydrolysis. Despite this resemblance they do not appear to belong to the reserpine class. Chronic toxicity tests on a concentrate of ester bases have not yet been completed.

The alkaloids of *Kopsia longiflora* appear to be of a type not previously encountered in the indole group, and attempts to establish the main skeletal structure have so far been unsuccessful. Further study of *Lunasia quercifolia* (previously thought to be *L. amara*) has revealed that the greater part of the alkaloidal material consists of water-soluble bases which are very susceptible to attack by alkali. They are thus converted to water-insoluble weak bases which appear as artifacts unless the conditions of extraction are carefully controlled.

(*d*) *Stock Poisons.*—Detailed studies have been made on pyrrolizidine alkaloids from *Crotalaria trifoliastrum, C. aridicola, C. goreensis, Senecio jacobaea, S. mikanoides, Heliotropium supinum,* and *Amsinkia intermedia.* The two principal alkaloids of *C. trifoliastrum* are also the major alkaloids of *C. aridicola*; one has been shown to be *O*-methylsupinidine. This work suggests that alkaloids are not the toxic factor in *C. aridicola* responsible for Chillagoe horse disease. Testing of the isolated alkaloids awaits the collection of more plant material. *C. lanceolata, C. intermedia,* and *C. goreensis* are also being examined with a view to determining their suitability as pasture legumes for Northern Australia; toxicity testing of the total alkaloids is in the hands of the Division of Animal Health and Production.

Work on *Senecio jacobaea* has centred round the structure of jaconecic acid which, together with *iso*jaconecic acid, is obtained from the alkaloids jacobine and jaconine. A detailed study of the products of the reaction with lead tetraacetate has helped to clarify certain features of the structure of this acid.

From *Heliotropium supinum* have been isolated the alkaloids supinine, heliosupine, echinatine, and a fourth new alkaloid. Isolation of the alkaloids of *Amsinckia intermedia* has proved unusually difficult, but two have now been obtained as essentially homogeneous gums and have been shown to be esters of retronecine.

Much time has again been devoted to assays of species likely to contain pyrrolizidines with the object of recognizing those which may be dangerous to stock. Assays have also been carried out at the request of agricultural and veterinary research workers in Western Australia and Queensland on species suspected of causing liver damage. Assays were also performed on *Symphytum peregrinum,* currently being considered for development in this country as a high-yielding fodder plant. Small amounts of several alkaloids, probably pyrrolizidine derivatives, were found.

Chemical investigation of the alkaloids of the Western Australian blue lupin is almost complete. The new alkaloid is dehydro-17-oxosparteine, an unusual modification of the sparteine type of alkaloid. A study of the Hofmann degradation of the alkaloids epilupinine and lupinine has shed some light on the stereochemistry of their quaternary salts. No racemization (as with cryptopleurine) has been observed, which indicates the need for a suitably situated unsaturated centre before this can occur.

Work is continuing on the toxic principle of *Atalaya hemiglauca* which is now believed to be an amino acid. A number of the non-toxic constituents of this species have been identified.

(*e*) *Root Exudates.*—Of the many problems in this field two have been selected for the initial studies. The first investigation is aimed at the isolation, from the root exudate of radish, of the substance which stimulates the growth of the pathogenic soil fungus *Pellicularia filamentosa.* In the second, attempts are being made to isolate the substances present in the root exudate of subterranean clover which influence the course of nodulation by *Rhizobium.* So far, the work has been concerned with setting up the necessary facilities and developing techniques for producing quantities of root exudates and assaying the biologically active substances contained in them. Chemical investigations are still in the preliminary stages.

In addition, the cause of the inhibition of germination of several species, including the commercially important hoop pine, by the leaf litter of *Backhousia augustifolia* is being studied. It has been shown that the main constituent of the essential oil of the leaves, the β-triketone augustione, inhibits the germination of cress and wheat. The activity of this substance and its effect on native species is being studied.

(*f*) *Fats and Related Long-chain Compounds.*—A project which has just been commenced will explore a new approach to the problem of converting naturally occurring long-chain acids, such as stearic, to less accessible and more valuable materials. Means will be sought to attack the molecules at positions normally unreactive; in this way a route could be opened to compounds similar to those formed in certain biological oxidations. Similar compounds are found occurring naturally in waxes such as carnauba, upon which they confer valuable physical properties. In preliminary experiments designed to discover suitable oxidation procedures, the reactions of fatty acids with some free-radical reagents are being studied.

Several new long-chain polyunsaturated acids and their *iso*butylamides have been prepared. These compounds are of potential insecticidal activity since they are closely related to a group of naturally occurring insecticides recently isolated from plant sources. Arrangements for testing have been made with the Division of Entomology, and it is hoped to obtain information on the relationship between structure and activity in this type of molecule.

Tigaso oil is obtained from the New Guinea tree *Campnosperma brevipetiolatum* and contains about 40 per cent. of an optically active component which has been shown to be an unsaturated long-chain hydroxydiketone related to the phenol campnospermonol, which is the major component. The new compound is of considerable interest since it represents a new class of natural product. Among its more interesting reactions is a remarkable pyrolytic fission into resorcinol and methyl oleyl ketone. The structure assigned to campnospermonol by earlier workers has been confirmed by synthesis of its methyl ether.

A preliminary investigation of the exudate from a related *Campnosperma* species from Malaya revealed the presence of a substance very closely related to the Tigaso oil compound. It differs only in the absence of one of the carbonyl functions and in the position of the double bond in the chain. From the biogenetic point of view the occurrence of these compounds is interesting, for they are probably precursors in the formation of the phenolic substance in the plant. Their structures closely conform to the acetate rule.

(*g*) *Tannin-Formaldehyde Adhesives.*—Work has continued on the mangrove-cutch adhesive with the object of further improving the water resistance and the strength of the bonded material. Lately the greater part of the work on this project has passed to the Division of Forest Products. Tests with the cutch adhesive fortified with a phenolic resin developed for the purpose have proved sufficiently promising to warrant a factory test. The results of this test were very satisfactory, and it is expected that commercial trials will be made.

(*h*) *Phenols of Brown-coal Tar.*—The problem of analysing the complex mixture of phenols present in the tar acids will be greatly simplified and more precise results will be obtained through the use of vapour-phase chromatography. Attention has been concentrated in the first place on establishing the technique for the separation of phenol mixtures and studying the behaviour of known mixtures of phenols. Two materials of opposite character, a hydrocarbon grease and a liquid polyester, have been found to produce resolution of certain mixtures of phenols of closely similar boiling point. A limited amount of work has been done on the extraction and fractionation of phenols from Lurgi tars, but the material so far available is not typical of the tars which will be produced when the plant of the Gas and Fuel Corporation of Victoria is in regular operation. This work is being performed in collaboration with the Physical Chemistry Section.

(*i*) *Microanalytical Service.*—The Microanalytical Laboratory, located at and operated as a joint activity with the University of Melbourne, provides a service essential to the conduct of all branches of organic chemical research. During the past year the Laboratory carried out approximately 6,500 separate analyses, an increase of 33 per cent. over the number for last year. Rather less than half of this number were for C.S.I.R.O. and other Commonwealth Laboratories, the remainder being requests from university (30 per cent.) and industrial laboratories (15 per cent.). It is particularly interesting to note the increasing volume of requests from outside Australia, amounting this year to 10 per cent. of the total, of which no fewer than 200 were from the United States.

(*j*) *Miscellaneous.*—A survey of the literature pertaining to the crystalline hydrates of alcohols and glycols has made it possible to identify the features which the molecule must possess in order to form a crystalline hydrate. The relationship has had some application in determining molecular structure.

A simple calculator has been designed and constructed for the conversion of percentage composition figures directly to all possible empirical formulae. The instrument functions for all elements and groups in any combination, and its range is limited only by the accuracy of the scales employed in its construction.

8. CHEMICAL ENGINEERING.

(Division of Industrial Chemistry.)

The research programme of this Section continues to be devoted mainly to projects dealing with the utilization of brown coal, applications of the technique of fluidization of solids, and the utilization of solar energy.

In the Process Equipment Laboratory numerous short-term process investigations were performed in collaboration with other sections and industrial companies.

(*a*) *Utilization of Brown Coal.*—This work is described in Chapter XIX., Section 5.

(*b*) *Application of Solids Fluidization.* (i) *Experimental Studies of Fluidized Solids.*—The use of a pressurized fluidized bed reactor in studies of brown coal hydrogenation has been described earlier. In conjunction with this work it has been necessary to investigate the fluidization characteristics of beds of brown-coal char over a wide range of operating conditions. The influence of the density and viscosity of the fluidizing gas has been studied, and methods of improving the quality of fluidization in deep, narrow beds are being examined.

Many experiments have been performed to help solve problems encountered in the introduction of coal at a high rate into the base of the reactor.

(ii) *Fluidized Bed Roasting of Copper Concentrates.*—The investigation of the fluidized bed roasting of copper concentrates has continued. All four major copper producing companies in Australia are now participating in this project.

A large number of experimental runs has been performed in the new 12 in. diameter fluidized bed roaster, and a major part of the planned programme has been completed.

An initial series of runs were performed to determine whether the performance of this unit could be correlated with that of the large 3 ft. 6 in. diameter pilot-plant roaster which had been used in previous work. Mount Lyell and Mount Morgan concentrates were employed as feed and the operating conditions duplicated those of a selected series of runs in the large unit. In the small roaster, however, the feed was introduced as a dry powder instead of a slurry in water, and temperature control was achieved by varying the temperature of the flue gas in the jacket surrounding the reactor instead of by water injection.

It was found that, provided allowance was made for the dilution of the roaster gases with water vapour in the 3 ft. 6 in. diameter reactor, the relationship between calcine properties and operating conditions was essentially the same in both units.

In a further series of runs the influence of gas space velocity and air/concentrate ratio on calcine properties and roaster performance was studied over a considerably wider range than had been possible in the large unit.

Finally a comprehensive series of runs covering the major operating variables has been performed with Mount Isa and Peko copper concentrates. Although some significant differences in the roasting behaviour of these concentrates have appeared, in general the results obtained are similar to those of runs with Mount Lyell concentrates.

(*c*) *Process Equipment Laboratory.*—This Laboratory provides facilities for technological experiments and the development of new chemical processes to the pilot-plant stage. The technical staff of the Laboratory are available to advise on the design of the experiments and supervise the use of the equipment by the staff of the organizations which initiate the work. Ten process studies have been conducted this year, five having been carried out by private companies. Special process equipment was made available on fourteen occasions, mainly for use by chemical manufacturers.

The work on the utilization of solar energy has been continued. Assistance has been given to the Physical Chemistry Section on the fire-fighting project.

XVIII. MINERAGRAPHY AND ORE-DRESSING.

1. GENERAL.

The importance of investigations for the development of the mining industry and the utilization of Australia's mineral resources is fully recognized by the Organization.

Mineragraphic work to provide information on the mineral composition of ores has been in progress in Melbourne since 1927. The techniques used are highly specialized and require considerable experience, so that it is only rarely that they can be applied by the staffs of operating mines. The current work of the Mineragraphic Investigations Section is described in Section 2 of this Chapter.

The Ore-dressing Laboratories operated in Melbourne in collaboration with the University Department of Mining, and in Kalgoorlie in co-operation with the School of Mines, investigate the composition of ores and provide advice on suitable methods for their full-scale treatment. This work is reported in Sections 3 and 4 of this Chapter.

Work on the utilization of minerals is carried out by the Division of Industrial Chemistry (*see* Chapter XVII., Section 2).

Mineragraphic Investigations Section.—The work of the Section has continued along the lines of previous years. More than 50 investigations have been made of the mineral associations of ores, rocks, drill cores, and mill products submitted by mining companies, the Ore-dressing Laboratories, and the Australian Atomic Energy Commission.

New equipment acquired during the year included: a Leitz Pan Phot, equipped with polarizers, for both transmitted and reflected light examination; a modernized lead-lap mechanical polishing machine; and a Beckman spectrophotometer.

Dr. F. L. Stillwell continued to work in the laboratories on a study of the mineralogy of the Broken Hill Lode.

Grateful acknowledgment is given to the University of Melbourne for continuing to provide laboratory accommodation, and to the various mining companies who have made contributions to support the work of the Section through the Australasian Institute of Mining and Metallurgy.

Ore-dressing Laboratory, Melbourne.—The most notable development in the work of the Laboratory during the year was the growth of co-operative investigations undertaken for mining companies. The two major projects were the flotation of base metal ores from Rum Jungle, Northern Territory, and the gravity concentration of oolitic iron ores from Roper Bar. The former investigation was undertaken for Consolidated Zinc Pty. Ltd., and the latter for the Broken Hill Pty. Co. Ltd. Both companies have made liberal donations to the funds of the Section.

In order to cope with these investigations, two additional members of staff were engaged in the one case, and an officer of the Broken Hill Pty. Co. Ltd. was seconded to the Laboratory in the second. This pattern for major co-operative investigations is likely to recur frequently. Both investigations are continuing.

In addition, many smaller investigations undertaken for mining companies by our own staff are sponsored on a cost basis.

In the expectation of continued financial support from the mining industry, contributed funds in hand are being used to pay the salary of a metallurgist recently added to the staff.

Despite the increasing proportion of work undertaken for major mining companies, the services of the Laboratory have remained available at nominal cost when circumstances have warranted this.

Ore-dressing Laboratory, Kalgoorlie.—The work of the Laboratory has followed the pattern of previous years. Eleven reports and 55 certificates were issued, eight of which related to gold ores, two to the ores of other metals, and one to a non-metallic ore. The certificates recorded mainly assays and analyses, and included numerous gold assays for the Government Geologist, whose drilling programme still continues.

No further work has been done this year on phosphate rock from Christmas Island, but the Senior Research Metallurgist visited the island during November and December to become familiar with operations there, and to discuss plans for pilot-scale tests with resident staff.

2. Mineragraphic Investigations.

(Mineragraphic Investigations Section.)

The Peko (Northern Territory) copper concentrate was studied with a view to a possible improvement of its grade, and the mineralizations in exploratory drill holes at Peko were examined also.

Lead ores from various drill hole intersections of the Brown's prospect, Rum Jungle, revealed the presence in the ore of nickeliferous linneite in some abundance, associated in places with very fine intergrowths of galena and chalcopyrite with pyrite, and with gangue.

A comprehensive survey of the mineralization in the Aberfoyle Tin Mine was completed. A great range of exsolution textures indicates that the deposit was formed from the penetration of hot mineralizing vapours (above 700° C.) into relatively cold country rocks (about 200° C.), and that the mineralization process was rapid. The base of the wolfram mineralization in the vein systems is marked by an incoming of sphalerite.

A similar study of the tin-tungsten mineralization at Moina, Tasmania, found a more or less parallel association of minerals and events.

A third study at Morning Star Gold Mine, Victoria, has revealed two periods of mineralization—an early, weak, copper-nickel-gold mineralization, and a later strong gold-quartz mineralization, with associated pyrite, arseno-pyrite bournonite, boulangerite, tetrahedrite, and galena.

Nickeliferous copper concentrate was examined from the Zeehan district, Tasmania; an unusual association of a hydrous nickel silicate mineral (garnierite), and of chromite, with bodies of the rare rock rodingite (garnetized gabbro) enclosed by serpentinite was investigated at Beaconsfield, Tasmania.

Uraninite at Milestone, Queensland, was found associated with haematite in brecciated basalt, while uraninite at Clear Waters, Northern Territory, brought to light an unusual form of radiation damage in enclosing albite felspar.

Beach sands containing valuable minerals have been examined from Mallacoota Inlet, and Mornington, Victoria, from Southport and northern Queensland beaches, from Capel, Western Australia, and from Fiji.

Further studies were made of amphibolites from the Broken Hill district, New South Wales; and shaft sections and bulk samples of the oolitic iron formations of Arnhem Land were examined in conjunction with testing at the Melbourne Ore-dressing Laboratory, conducted jointly with the Broken Hill Proprietary Co. Ltd., as to the suitability of the iron formation for beneficiation. A similar iron formation from Constance Range, Queensland, was also examined.

Boehmite was identified in the Weipa bauxite deposits; and the occurrence of lead in several old slag dumps was investigated.

3. Ore-dressing Investigations.

(Melbourne Laboratory.)

There has been the expanding interest in the concentration of minerals from beach sands. The high price for rutile brought many new areas into production and the Laboratory was kept busy checking the behaviour of new samples and investigating new problems, particularly methods of dealing with coated minerals.

A related investigation of current interest is the concentration of a rock utile ore from Queensland. Flotation methods are showing some promise.

The recovery of ilmenite from Western Australian deposits also became commercially established during the year, and the Laboratory undertook investigation of samples from two of the important areas.

Several investigations in the concentration of uranium ore were undertaken. It has now become clear that the future of the smaller and more remote uranium ore bodies will depend increasingly on concentration, since there are significant tonnages of ore which cannot profitably be transported to treatment plants.

Substantial progress was made in controlling readily flotable gangue in base metal ores from Rum Jungle. Flotation of copper cobalt ores in acid circuit proved feasible but unattractive because of high cost. For some time, flotation in alkaline circuit failed, but eventually success was achieved by following a rigid conditioning procedure. The process has recently proved successful in pilot-plant trials, and a treatment plant is, at present, being designed.

However, this process is far less successful for treating the substantial tonnages of lead ores in the region, and alternative methods are being vigorously investigated.

Flotation of cassiterite from the tailings of a small base metal mill in New South Wales was investigated, and tests were distinctly encouraging. Plant-scale trials are likely very shortly.

The flotation of fluorite was investigated. Fluorite is likely to be of increasing importance in Australia when large-scale aluminium production commences.

Progress was made in investigating conditions for pressure leaching of a manganese ore using added pyrite as a source of sulphur. The investigation included a study of the kinetics of some of the stages of the reaction process.

The Section co-operated with the Division of Industrial Chemistry by investigating the extraction of gold from calcines produced by fluo-solids roasting of copper concentrates from Mount Morgan and Mount Lyell.

4. ORE-DRESSING INVESTIGATIONS.

(Kalgoorlie Laboratory.)

The full-scale Edwards-type roaster referred to last year has now been installed, together with a second roaster of a modified type. Metallurgically these have proved more satisfactory than the older Edwards roasters, but some mechanical engineering problems have still to be overcome.

The pilot-scale test work on a graphite ore from Munglinup was satisfactorily completed, and confirmed earlier batch tests. The concentrate produced assayed just under 86 per cent. graphitic carbon and contained just under 82 per cent. of the carbon in the feed to the plant. The concentrate was shipped to prospective buyers in the eastern States and in America.

Tests were carried out in some calcine residues containing 4.2 dwt. gold per ton. Four series of tests were tried, and it was found that the gold could be volatilized in the presence of salts such as sodium chloride or copper sulphate or in an atmosphere of chlorine. The processes were not, however, thought to be economic, and the calcines still remain untreated.

Concentration tests were carried out on a sulphide copper ore from Ravensthorpe, Western Australia, and high-grade copper concentrates were produced by selective flotation. Recommendations for treatment of this ore were made, and a plant is now in operation.

Test work on a gold ore containing arsenopyrite and coming from near Bullfinch showed that 80 per cent. of the gold could be recovered by straking followed by flotation, and roasting and cyanidation of the concentrates.

A copper ore coming from the vicinity of Marble Bar was submitted to the Laboratory for examination. It was found that approximately 80 per cent. of the copper in the ore could be recovered as a sulphide concentrate containing 40 per cent. copper. A treatment process was recommended and a plant is now in operation.

XIX. FUEL.

1. GENERAL.

Coal is Australia's principal source of energy. Available resources of the more valuable types are, however, limited, and it is essential to widen the knowledge of their properties in order to make the best and fullest use of them.

The Organization's main centre for investigations on fuels is the Coal Research Section, located at North Ryde, New South Wales. This Section was established to undertake, on a national basis, a comprehensive study of the physical and chemical characteristics of Australian coals.

The Division of Industrial Chemistry undertakes work on the engineering aspects of the gasification of low-rank coals, and this work is reported in Section 5 of this Chapter.

Co-operative investigations on the fossil pollens in brown coal are undertaken in the Botany School of the University of Melbourne (*see* Section 4 of this Chapter).

Coal Research Section.—Steady progress is being made in increasing the laboratory facilities and recruiting and training the necessary staff to cover the full programme of research projects eventually to be undertaken by the Section. However, the number of essential projects in hand continues to strain the limited resources available, and research is still severely restricted in some important fields, e.g. the combustion characteristics and mechanical properties of Australian coals.

Members of the Section continue to make a major contribution to the activities of the Institute of Fuel. The Officer-in-charge has been appointed as the Organization's representative on the Council of the Institute, and was invited to present a paper on the work of the Section to the Institute in London last October. The Officer-in-charge was also Chairman for the second year of the Australian Membership of the Institute, and in November delivered an address in Sydney on " World Energy Trends in Relation to Australia's Fuel Problems ". Although a number of the Section's officers received invitations to attend overseas conferences, owing to pressure of work only one of these could be accepted, namely, that to the Gordon Research Conference at New Hampton, United States of America, in June.

The Section continues to receive a large number of technical inquiries from industry and the general public, which deal with a wide variety of topics within the fields of coal science and technology.

During the year the first issue was published of a new periodical entitled *Coal Research in C.S.I.R.O.* It is intended that this publication will form a link between the Section and all those who are concerned with the production and utilization of coal.

2. COAL UTILIZATION.

(Coal Research Section.)

(*a*) *Carbonization Investigations.*—Perhaps the greatest individual problem in the utilization of Australian coals at the present time is that of modifying the technique of carbonization in such a way as to produce better metallurgical and foundry coke. The demand for coke for both blast-furnace and foundry purposes is rising rapidly, and vast expansion of coke manufacturing facilities is anticipated in the near future. At the same time available resources of good coking coals are limited, so that ways have to be found of making metallurgical coke from less suitable seams. A major proportion of the Section's effort is therefore devoted to carbonization research.

(i) *Pilot-plant Investigations.*—For use in this work several pilot-plant carbonizing units have been constructed and put into operation, namely:—

B.M.-A.G.A. coking unit—100-200-lb. charges;
Illinois slot oven—500-lb. charges;
Sole-heated expansion oven—40-lb. charges.

Other units employing moving-burden techniques are in process of construction and development.

The B.M.-A.G.A. unit gives detailed information on the quantity and quality of coke, gas, tar, and other by-products; the Illinois slot oven allows larger-scale tests, more closely approaching industrial coke-oven conditions, to be made on the suitability of individual coals and of coal blends for the production of metallurgical coke; the sole-heated expansion oven enables the swelling properties of coals during carbonization to be measured and shows the effect of modifications to their properties designed to enable strongly swelling coal to be coked without risk of accident in commercial coke ovens.

Much of the future industrial development in northern Queensland will depend on adequate supplies of clean coal and good-quality metallurgical coke, requirements for which are expected to increase substantially in the next ten years. To mention only one example, Mount Isa Mines Limited expect their consumption of coke for smelting operations to quadruple within the next few years. As this company's supplies of coal and coke have to be hauled by rail over 600 miles from the coast, coal of minimum ash content and coke of good mechanical strength are important.

Work by the Section during the year under review has provided the basic information needed for the construction of the coal washing and coke oven plant needed in northern Queensland to provide increased supplies of high-quality coal and coke. A comprehensive examination was made of samples from the Bowen and Blake seams of the Collinsville coal measures, situated about 700 miles north of Brisbane. It was found that the Bowen seam is one of the best coking coals investigated to date in the Section.

Many factors affecting the manufacture of metallurgical coke from the Bowen coal were investigated including selective preparation, fineness of grinding, oxidation due to weathering, rate of carbonizing, and blending separately with coke fines and Blake coal; recommendations on the best ways of using these coals were made accordingly. The investigation showed that up to 40 per cent. of the less valuable Blake coal could be blended with the better Bowen coal without affecting the quality of the coke appreciably.

Routine B.M.-A.G.A. tests on coal samples from the Liddell seam, New South Wales, and from the Kemmis Creek area of the Nebo coalfield, Queensland, showed that the first coal is a good gas-making coal and that the second is not suitable for making either gas or coke.

Tests are continuing on three important New South Wales coals to determine the effect of weathering on carbonizing behaviour.

Experiments have shown that it is possible to improve certain physical properties of gas coke made from the high-volatile Greta coal by mixing with a lower-volatile poorly coking coal.

(ii) *Petrology of Coal and Coke.*—In conjunction with these coking tests, petrographic and plastometric measurements have been carried out on all the coals concerned. This work indicates that the petrographic constitution of a coal is closely related to its coking properties, and the results provide objective and quantitative information on how coal charges should be prepared for carbonization.

The investigation of the Bowen and Blake seams, already mentioned, included examination of the petrology of the seam profiles and of the effects of coal preparation. The cokes were similarly examined, particularly with respect to their optical properties and vesicle structure.

(iii) *X-ray Studies of Coals and Cokes.*—Another technique which has been used to lay bare the facts relating to the physical structure of coals and cokes is that of X-ray diffraction. Assuming that the basic structural units are graphitic " crystallites ", their spacings and dimensions and the degree of graphitization have been estimated by X-ray measurements, the reproducibility of which has been determined by photographic means.

The diffraction patterns of coals and cokes consist of diffuse haloes, the physical interpretation of which is a difficult and laborious process. The computing work involved has been greatly reduced by employing the SILLIAC electronic computer, in the School of Physics at the University of Sydney, for solving problems involving Fourier synthesis. A complete programme for the computer has been worked out, enabling atomic radial distribution curves to be obtained from X-ray data of coals and cokes.

(iv) *Fundamental Coking Phenomena.*—An investigation is in progress of the chemical mechanism of coke formation. The pyrolysis of some polynuclear aromatic compounds is closely analogous to that of coals. Above a carbonizing temperature of 500° C. changes were noted in these compounds similar to those observed on heating coking coals. By studying the infra-red and electronic spectra, the X-ray diffraction patterns, and solubilities in sulphuric acid of the semi-cokes and chars produced, advances have been made towards understanding their structure.

Furthermore, by heating samples of these compounds to 1000° C., examining the volatile matter, and making an ultimate analysis of the semi-cokes produced, evidence was obtained to support the view that the volatile matter from coal does not necessarily originate solely from the substituent groups in the polynuclear aromatic system.

This long-range fundamental work on coking phenomena is continuing in parallel with short-term investigations bearing on the immediate problem of how to make better coke. These comprise measurements with the Gieseler plastometer, with the Audibert-Arnu dilatometer, and with the differential thermobalance to follow the physical processes of softening, fusion, swelling, solidification, shrinkage, and chemical decomposition as coal is converted into coke.

The process of the softening of coal, provided no actual decomposition had occurred, was observed to be reversible to a limited degree with temperature, the effect being somewhat analogous to the melting of pitch. This softening, which corresponds to the development of a rudimentary type of plasticity, is believed to be caused by the release of mobile structural units of relatively low molecular weight arising from depolymerization, together with the reduction in viscosity of this material as the temperature rises.

Experiment has shown that the heating régime during carbonizing has profound effects on fluidity, swelling, rates of decomposition, and shrinkage during solidification, and that the magnitude of these changes determines in some measure the physical structure of the coke produced.

It has been found that by adding a small percentage of pitch to a coal of low fluidity a material is produced having high fluidity with wide plastic-temperature ranges as measured by the Gieseler plastometer. With an anthracitic sample, however, it is necessary to add as much as 28 per cent. of pitch before plasticity of the mixture can be induced.

(*b*) *Chemicals from Coal.*—The manufacture of chemicals from coal via coal tar is the basis of a valuable industry in Australia. The Section is therefore continuing its investigations into the properties and constitution of coal tars as an integral part of the carbonization programme.

The data from analyses of tars and scrubber naphthas have been used to correlate the yield and the constitution of each tar and naphtha with the conditions of carbonization and the rank of the coal charged (as expressed by the hydrogen content of the d.m.m.f. coal).

The phenolic and basic groups in tars and pitches are being estimated by non-aqueous potentiometric and high-frequency titrations and infra-red spectra. The results of some of this work are also likely to prove of value to investigations of the basic structure of coal.

An investigation is being carried out into the chemical nature of brown coal, with the object of developing processes for the production of chemicals. As the first stage in the work a study was made of the distribution of active oxygen-containing groups in four Victorian brown coals. The groups accounted for 70–80 per cent. of the total oxygen.

(*c*) *Coal Preparation.*—Studies of the techniques of coal preparation form another part of the carbonization programme mentioned above, the emphasis again being on the implications so far as metallurgical coke production is concerned.

During the year the washability characteristics were determined of New South Wales coals from the Liddell and Bulli seams, and of Queensland coals from the Bowen and Blake seams and the trial shaft at Kemmis Creek. It was found that it would not be economical to wash the main output from the Bowen seam, but with the Blake seam a high yield of coal of considerably lower ash content could be separated by suitable cleaning equipment.

Good results were obtained from the radiography apparatus installed last year. By this means the distribution of minerals in coals can be examined much more effectively than is possible with the naked eye.

The trend towards the use of mechanical coal-cutting equipment has been accompanied by a general rise in the ash content and in the percentage of fines in colliery outputs. The problems of cleaning small coals are therefore of increasing importance. In the Coal Research Section work on these problems has continued with the hydrocyclone concentrator. Fundamental investigations into the froth flotation of coal are also continuing with the aim of assessing the flotation characteristics of coal in terms of two or three parameters. The small-scale continuous flotation plant has been used to investigate the effect on the rate of flotation of such variables as feed rate, pulp density, and frother concentration.

(*d*) *Combustion Investigations.* (i) *General.*—The mineral matter in coal may give rise to troublesome deposits, clinkers, and slags, when the coal is used as a fuel, and practical means for alleviating this problem are being studied in the Section. In particular, the combustion-pot furnace technique is being used to study the fusibility characteristics of the mineral constituents as they occur in coal. In this way it is possible to assess (1) the effect of the nature and distribution of mineral impurities; (2) the relative importance of mineral impurities which can be removed by washing and of those which cannot; (3) the effect of such operational factors as air rate, air preheating, fuel particle size, and bed thickness. This problem is being attacked also by means of observations with a Leitz heating microscope, which enables the fusibility of coal minerals, ashes, and clinkers to be investigated at high temperatures.

A spectrophotometric method has been developed for the rapid analysis of coal ash and similar materials.

A combustibility index has been devised which indicates the ease of burning of the coal, this being expressed in terms of heat release, ash-pit loss, and the amount of combustion air supplied. The value of this index has been determined for coals examined in the Section's seam assessment programme, representing the following seams: Young Wallsend, Tongarra, Rathluba, Lithgow, Homeville, Greta, Borehole, Ashford, and Muswellbrook.

An evaluation was made of the combustion characteristics under overfeed- and travelling grate-firing conditions of various specific gravity fractions of the Bowen and Blake coals.

(ii) *Pore Structure of Coals and Cokes.*—Some coals and cokes are more readily burnt as fuel, or gasified to form producer gas or water gas, than others; the difference is measured in terms of their "reactivity". This may be a function of the internal surface area accessible to oxygen or other gases, which means that it would be affected by the micropore structure of the particular coal or coke. The combustion research programme has therefore included measurements of the micropore structure of coals and cokes, based on measurement of apparent densities in a series of liquids having a range of molecular volume. This work has confirmed the view that coals and cokes are composed of structural units containing fine pores connected by much larger pores.

Measurement of the adsorption isotherms of water by cokes was found to be unsuitable for the calculation of surface areas, but acetone gave normal isotherms, and surface areas calculated therefrom were in close agreement with those obtained with nitrogen.

The size distribution of the larger pores in coke and the changes in structure during gasification are being determined by measurement of the penetration of mercury in a high-pressure porosimeter.

3. COAL SEAMS AND STRATIGRAPHICAL STUDIES.

(Coal Research Section.)

(*a*) *General.*—The detailed assessment of the chemical, physical, and petrographic characteristics of selected coal seams and their subsections has been continued as in previous years. Coals from twenty collieries in the Southern Coalfield of New South Wales representing the Bulli, Wongawilli, and Tongarra seams were examined again, the first examination having been made three to four years previously. This work will supply the information needed for a comprehensive report on the Southern Coalfield.

Considerable attention was paid to coals from Queensland, in view of the great industrial potentialities of this State, and as has already been mentioned the Bowen and Blake seams of the Collinsville coal measures in northern Queensland were sampled at Scottville and examined in detail.

During the year under review a trial shaft was sunk in the Kemmis Creek area, Nebo Coalfield, by the Queensland Mines Department, in collaboration with the Bureau of Mineral Resources, to enable the coal resources in this area to be evaluated more precisely. Full profile samples were taken by this Section and examined in detail.

In the Northern Coalfield of New South Wales samples from the Liddell seam were examined.

(*b*) *Petrography.*—During the year under review petrographic analyses have been made of samples of coals from New South Wales and Queensland, as well as of coals from Australian territory in Antarctica. The Southern Coalfield of New South Wales has been the subject of an especially detailed study.

Petrological examination has been made of various thermally metamorphosed coals from the vicinity of igneous intrusions, and the results may prove to be of assistance in elucidating the mechanism of the carbonization process.

(*c*) *Palynology.*—The Section possesses considerable knowledge in this field from studies of the microfossils of coal measures, and this knowledge has been placed at the disposal of oil exploration companies, in particular the West Australian Petroleum Company during its reconnaissance surveys in Western Australia. During the year under review age determinations were carried out on about 300 samples of carbonaceous sediments.

Examples of the contributions made by these studies are the demonstration of the existence of Uppermost Permian and probable Lower Triassic deposits in the Geraldton and Mullewa area, and the discovery of a thick Mesozoic section in a borehole at Mullewa. It was also found that the Donnybrook Sandstone in Western Australia should probably be placed in the Lower Cretaceous. The geological implications of these palynological determinations are of considerable importance.

An account has been prepared of the spore species occurring in samples of Western Australian Mesozoic sediments examined by the Section, together with a discussion of their stratigraphical significance.

An extensive palynological examination has been made of samples from various New South Wales seams. In the course of this work the presence of various spores and pollen grains has been noted and their geological implications are being assessed.

4. MICROSTRUCTURE OF BROWN COAL.

(Pollen Research Unit.)

The work of the Pollen Research Unit, at the Botany School, University of Melbourne, has been largely concerned with pollen and phytoplankton contents of Tertiary and Mesozoic sediments. A large report listing many new species of microplankton from the Upper Mesozoic sediments of Australia and New Guinea has been completed in conjunction with Professor A. Eisenack of the University of Tubingen, Germany.

Megaspores, some of them identical with forms in the Wealden of England and the Netherlands, have been discovered in the Upper Mesozoic sediments of south-east Australia and are being studied.

Work on the pollen analysis of a complete section of the Yallourn brown coal seam has continued. The results, though incomplete, suggest a regular pattern in the vegetational development during the formation of the coal. The slow progress is due largely to the necessity of making a detailed study, now completed, of the pollen of living and fossil species of *Casuarina*.

A ligneous clay overlying the Morwell No. 1 coal seam has provided numerous leaf remains which appear to be the first recorded occurrence of *Eucalyptus* in association with the brown coals.

Megaspores and massulae of the water fern *Azolla filiculoides* were found in a Quaternary deposit near the River Yarra, at Melbourne.

5. UTILIZATION OF LOW-RANK COAL.

(Division of Industrial Chemistry.)

Considerable progress has been made during the past year in basic studies of the chemical reactions which are of importance in the pressure gasification of brown coal. As a result of this work a more complete understanding of the gasification process is emerging.

(*a*) *Gasification of Brown Coal with Hydrogen.*—The investigation of the production of methane by the gasification of brown coal with hydrogen in a continuously operated fluidized bed reactor has continued. A comprehensive series of experiments in which the operating pressure was varied from 300 to 600 lb./sq. in., the reaction temperature from 500 to 850° C., and the gas/coal ratio from 20 to 140 cu. ft./lb. has been completed. In all these experiments the coal was introduced into the base of the reactor as a suspension in the hydrogenating gas stream. The reaction bed was 3 inches in diameter and 39 inches deep.

At constant coal feed rate the rate of methane formation and the degree of gasification were found to increase with increased temperature and hydrogen partial pressure. Increase of coal feed rate at constant temperature and pressure increased the rate of methane formation but decreased the yield of methane per pound of coal and the degree of gasification. The maximum methane yield obtained so far was 10.1 cu. ft./lb. (225 therms/ton), the coal in this case being 75 per cent. gasified.

The molar ratio of methane formed to hydrogen absorbed was always higher than 0.65; thus carbon atoms with hydrogen atoms attached are hydrogenated preferentially. As this coal hydrogen is progressively consumed (as shown by the hydrogen content of the residual char) the rate of gasification falls sharply.

When the results of these experiments are compared with those of similar experiments performed in a static bed reactor, it is seen that, in cases where the coal is gasified to the same extent, more methane is produced and less hydrogen is absorbed in the fluidized reaction system. It is apparent that in the static bed experiments some of the coal hydrogen was lost by pyrolysis before the temperature of the coal particles reached a level at which the hydrogenation reaction proceeded rapidly. The almost instantaneous heating of the coal particles when they entered the fluidized bed avoided this.

So far it has not been possible to achieve simultaneously the production of gas of high calorific value and a high degree of gasification of the coal. It is clear that a much deeper reaction bed and hence a longer particle residence time will be required if this is to be feasible. Experiments to provide data for the redesign of the reactor are proceeding.

(*b*) *Steam-carbon Reaction at High Pressure.*—A study of the kinetic features of the reaction between carbon and steam over the pressure range 1-50 atm has been completed. The data obtained in this work have provided an explanation for a number of puzzling features in the results of previous investigations, and have led to a new conception of the mechanism of this reaction at high pressures.

The primary products of the reaction were shown to be carbon monoxide, hydrogen, and methane. The fraction of the carbon gasified as methane increased with increased pressure and decreased temperature.

Under conditions where the fraction of carbon gasified as methane was low, the reaction was found to be approximately first order with respect to steam, and was strongly retarded by hydrogen. The magnitude of the hydrogen retardation is such that if more than about 10 per cent. of the steam is converted the overall reaction rate is only slightly increased by large increases in pressure.

The methane formation rate was always found to be independent of the hydrogen pressure but of first order with respect to steam. When the fraction of carbon gasified as methane was appreciable, the rate of carbon monoxide formation was considerably higher than would be expected from a reaction of first order with respect to steam.

It is considered that most of the methane must be formed by reaction between steam molecules and certain favourably placed carbon atoms to which two atoms of hydrogen are attached. The oxygen from these steam molecules reacts with adjacent carbon atoms and forms carbon monoxide. An overall rate equation which takes account of this mechanism was found to correlate satisfactorily the whole range of experimental data.

XX. PHYSICAL METALLURGY.

1. GENERAL.

A programme of research on special projects in the field of metallurgy is undertaken at the Section of Physical Metallurgy established in the Research School of Metallurgy at the University of Melbourne. This work is described below. Work on metal physics is in progress within the Division of Tribophysics (*see* Chapter XXI.). The work of the Division of Industrial Chemistry on foundry sands is reported in Chapter XVII., Section 4.

Section of Physical Metallurgy.—The research of the Section has continued along lines which have emerged from the work of previous years, and no major charges have been made to the investigational programme.

One new activity has been the construction of microbeam X-ray equipment which will be used in more detailed studies of the deformation of metal crystals.

Members of the Section have continued to assist in the supervision of post-graduate students and have played a major part in the conduct of post-graduate discussion groups. The Section continues to answer a large number of enquiries from industry on problems in the metallurgical field.

2. TITANIUM AND ITS ALLOYS.

(Section of Physical Metallurgy.)

(*a*) *Alloys.*—Measurements of internal friction and rigidity modulus in titanium and its alloys have been continued.

An internal friction peak due to the presence of oxygen has been observed at about 400° C. and the influence of alloying additions of aluminium, zirconium, and oxygen on the characteristics of this peak has been examined. The behaviour of the rigidity modulus in this temperature range has been found to be anomalous, and possible mechanisms for describing the observed phenomena have been considered.

An effect of creep on internal friction has been observed in the temperature range above the oxygen peak, and it is suggested that creep makes a significant contribution to the background internal friction at high temperatures.

(*b*) *Analytical Methods.*—The permanganate-arsenite titration method for the estimation of manganese in titanium has been investigated, and improved by the addition of fluoride ions. A differential absorptiometric method for the estimation of titanium in beach sand ores has been developed in collaboration with the Ore-dressing Section.

3. DEFORMATION.

(Section of Physical Metallurgy.)

The study of the recrystallization of lead during creep has been continued and the influence of interrelated variables such as stress, grain size, purity, and annealing conditions further delineated; some suggestions on the mechanism of the phenomenon are being worked out. The migration of grain boundaries during creep has also been measured, partly in connexion with the study of recrystallization and partly in an attempt to see whether boundary migration is the rate-controlling process during creep. Comparative measurements have also been made of the rates of grain growth in similar specimens during annealing, and the distribution of grain sizes after various annealing treatments has also been determined.

The apparatus for zone-refining of lead has been rebuilt, and preliminary results indicate that the degree of refinement is satisfactory. The concentration of copper along the refined bar has been determined by a colorimetric method, and procedures for determining exceedingly faint traces of some other impurities have been investigated.

An apparatus has been designed and built to grow " seed " single crystals of lead *in vacuo* and then to use the seeds to grow bi-crystals of controlled orientation, also *in vacuo*. From the bi-crystals, specimens are cut by chemical cutting for creep tests for the study of boundary sliding.

In conjunction with the Metallurgy Research Department of the university an X-ray microbeam set is being built. One use of this will be to study the structures developed within the grains, especially close to the boundaries, in both polycrystals and bi-crystals during creep.

XXI. TRIBOPHYSICS.

1. GENERAL.

The Division of Tribophysics has developed from the former Lubricants and Bearing Section established during the war to assure Australian engineering industry of essential information in the manufacture of bearings for aero and other engines. The original investigations have been continued and extended to include fundamental studies in metal physics and the surface physics and chemistry of solids. Major advances have been made in the knowledge of distortions in metals produced by plastic deformation and of topology and reactivity of metal surfaces.

This chapter describes the current research of the Division of Tribophysics. In Chapter XVI., Section 7 (d), a brief account is given of a project on the basic study of friction in the Wool Textile Research Laboratories as part of the research on the felting properties of wool.

Division of Tribophysics.—As in previous years, the Division has co-operated with the Chemistry, Metallurgy, Mining, Physics, Mathematics, and Engineering Departments of the Melbourne University and is indebted to these Departments for the use of many facilities. An officer has been seconded to the Chemistry Department to work on problems of the solid state.

Advice and assistance have been given frequently to numerous industrial firms, government organizations, university departments, and other Divisions of the Organization. The range of subjects—lubrication, bearings and bearing metals, wear, metals technology, electrolytic polishing, electronics, and surface chemistry—illustrates the way in which the fundamental investigations of the Division are related to practical applications.

The Division has expanded its industrial liaison by engaging in co-operative research with the Broken Hill Associated Smelters Proprietary Limited on some fundamental aspects on the refining of lead. A general survey of available information was carried out, and experimental work was conducted on some aspects of the dispersion of one fluid in another, an operation fundamental to most lead-refining processes. In particular, the behaviour of gas bubbles in lead has received attention.

Officers of the Division have continued to act on various committees, in particular, the C.S.I.R.O.-Department of Supply Engineering Group Committee, the Lubrication Committee of the Department of Supply, and the Committee on Viscosity of the Standards Association of Australia.

One officer attended the International Conference on Dislocations and Mechanical Properties of Crystals, at Lake Placid, U.S.A., and another officer the Royal Society Discussion on Work Hardening and Fatigue in Metals at London.

2. PROPERTIES OF SURFACES.

(Division of Tribophysics.)

Apart from investigations on some practical aspects of friction and lubrication, the work on the physics and chemistry of solid surfaces is concerned mainly with the state of a surface after preparation by various methods (sputtering, mechanical polishing, thermal etching) and with the chemical properties of such surfaces. Any chemical reaction taking place on a surface involves three stages: adsorption of reactants, rearrangement of the adsorbed molecules, and desorption of the reaction products. In studies of surface activity these stages should be considered separately.

(*a*) *Friction and Lubrication of Bearings.*—The programme of bearing testing has been continued, with the use of highly finished bronze bearings running on hardened and superfinished journals. This combination of surfaces reduces the effects of running-in on bearing geometry, and has enabled the effect of curvature of the shaft on bearing friction to be evaluated. Such curvature is always present in shafts which are subjected to bending by the applied load, and it is shown that there is a significant effect on friction in some practical cases.

(*b*) *The Structure of Solid Surfaces.* (i) *Sputtering.*—Studies of surface phenomena very often use sputtering (erosion of surfaces by positive ion bombardment) as a method of producing a clean surface representative of the bulk material. Although it has been studied for 100 years, sputtering is not well understood and consequently new methods of studying sputtering phenomena have been developed.

It has been found that the surface being sputtered is severely distorted. In addition, if the material being sputtered is an alloy the surface is altered in composition. These and associated observations are expected to indicate how a surface may be best prepared for a given research problem.

(ii) *Mechanical Polishing.*—It is commonly believed that mechanically polished surfaces are inevitably heavily deformed by the polishing, even to the extent of being covered with a thin structureless layer known as a Beilby layer. A critical survey of past investigations reveals that no attempts have been made to polish in such a way that this distortion of the surface is kept as small as possible. Experiments with silver single crystals have shown that it is, in fact, possible to prepare highly polished metal surfaces which are only slightly deformed. It has been found that the distortion retained in the surface decreases as smaller abrasive particles are used for polishing. A crystal, polished so that the deformed layers are removed as polishing progresses, has a surface which is very flat and deformed by such a small amount that there are crystal misorientations of only about ±5° at the surface. There is no Beilby layer on such specimens.

(iii) *Thermal Etching.*—When silver is heated in air to temperatures near its melting point a series of fine ridges are formed on the surface. One face of the ridges is a

(111) or (100) plane depending on the orientation of the silver surface, and the other face of the ridges is a plane of random orientation. Measurements of the angles and relative areas of the faces of these ridges have yielded information about the relative surface energies of (111) and (100) planes. Experiments have also been carried out to follow the development of the ridges during etching. Contour measurements with a stylus needle and by means of multiple-beam interferometry have shown that the ridge develops by transport of material along the low-indices face. The different transport mechanisms are being investigated.

(*c*) *Chemical Properties of Surfaces.* (i) *Adsorption of Long-chain Compounds on Crystals.*—It was reported last year that a study was being made of the adsorption of dodecyl sulphate on barium sulphate. It has been found that barium sulphate precipitates in different crystal habits depending on the conditions of precipitation, and it is intended to study the adsorption properties of the different crystals. So far, attention has been confined to one powder in order to define more exactly the processes of the adsorption of monolayers and bilayers and the precipitation of dodecyl sulphate by barium ions. Difficulties have arisen in reproducing results in the range of concentrations giving rise to hydrophobic particles and flocculation, but these have been overcome by proper conditions of agitation. An apparatus has been constructed for determining surface areas by low-temperature krypton adsorption.

(ii) *Thermal Desorption of Stearic Acid from Silver.*—Experiments are being undertaken to investigate the role played by crystal orientation on the forces by which long-chain polar molecules are attached to metal surfaces. Radioactive monolayers of stearic acid are deposited, by the Langmuir-Blodgett technique, on single crystals of silver whose surfaces have been electro-polished and sputtered. Desorption isotherms are being determined for crystals of different orientation. It has been found that a Geiger counter can measure the small quantities of radioactive material down to fractions of a close-packed monolayer.

(iii) *Catalysis on Single Crystals of Silver.*—For catalytic reactions on metals the relevant factors are the rate of reaction, the activation energy, and the temperature independent factor of the Arrhenius equation. In the study of the catalytic decomposition of formic acid on single crystals of silver of different orientations, it has been found that the values of these factors can be drastically changed by surface treatment.

Further experiments carried out on electrolytically polished and sputtered and on thermally etched and sputtered surfaces confirmed the earlier results and showed that the activation energy is almost independent of orientation. The effect produced on sputtering is an apparent homogenization of the surface, and a new surface structure is developed which differs from the underlying material.

The activation energy depends on the orientation of thermally etched crystals if they expose (111) facets. These crystals are catalytically more active than the sputtered surfaces, though the changes in activation energy and in the temperature independent factor largely compensate each other.

In contrast, the activation energies obtained on surfaces which expose (100) facets only are similar to those obtained on sputtered specimens. The observed increase in rate of reaction can be related to the increase in surface area due to etching.

3. METAL PHYSICS.

(Division of Tribophysics.)

Although a material of specified properties is far from being synthesized, this work will promote a further understanding of the nature of the strength of materials and the mechanism of plastic deformation.

It is well known that the strength of metals is about 1,000 times smaller than the value expected from forces which hold the atoms together. The fault here is with the materials and not with the theory, since strength values up to 1,000,000 lb./sq. in. have recently been measured on very thin metal specimens. The reason for the low strength usually observed is that most crystals are imperfect. These defects in crystals not only cause the strength to be low but they make it possible for plastic deformation to occur. That defects are responsible for these effects has been suggested for a considerable time, but direct evidence for their existence has become available during the last twelve months. In order to produce a material of high strength one has either to make crystals without defects or lock the defects so that they cannot move, as their movement is the mechanism of plastic deformation.

The types of defects occurring in deformed metals are dislocations (displacements of atomic planes in a vernier-like fashion), vacancies (atoms missing from the orderly array in a crystal), interstitial atoms (extra atoms in the crystal), and stacking faults (extended dislocations). The behaviour of crystals in general, and particularly the hardening due to plastic deformation, is largely influenced by the interaction of defects with each other, as this inhibits their movement. In order to understand the origin of work hardening, one has to know the type, the number, and the arrangement of defects in plastically deformed crystals. To this end, several properties of metals (internal energy, density, electrical resistivity, hardness, and shape of X-ray diffraction lines) have been measured after various deformation and annealing treatments.

(*a*) *Density of Dislocations in Deformed Metals.*—The concentration of dislocations in metals increases rapidly during plastic deformation. Independent estimates of the density of dislocations resulting from plastic deformation can be obtained by measuring the changes in different properties, on the same material, which accompany the plastic strain. In the previous report it was indicated that the density of dislocations in deformed nickel, as calculated from measurements of density, was considerably higher than that calculated from measurements of stored energy. To check whether this was a general result, measurements of stored energy and density have been made on pure copper and a discrepancy was found for this material. However, recent theoretical work overseas has shown that dislocations cause a change in density considerably larger than assumed previously, and on the basis of these new calculations the discrepancy is removed.

However, for both nickel and copper the density of dislocations calculated from measurements of the changes in electrical resistivity accompanying annealing are 60 times greater than the densities of dislocations calculated from the measurements of stored energy and density. It is suggested that this discrepancy is due to stacking faults making a large contribution to the measured change in electrical resistivity.

(*b*) *Interaction of Dislocations and Solute Atoms.*—The motion of dislocations in crystals during deformation and recovery processes is hindered when solute atoms segregate around them so as to form " atmospheres ". Such atmospheres produce a " yield point " in the tensile test of a single crystal. Very pronounced yield points have been observed in single crystals of a copper-arsenic alloy. In addition, a non-linear increase of the electrical resistance near the yield point has been observed, and this provides new supporting evidence for the formation of atmospheres. Similar behaviour is not observed in pure copper. These results agree with, and assist in the interpretation of, previous measurements of stored energy and electrical resistivity on copper-arsenic alloys.

(*c*) *Stacking Faults.*—As mentioned above, discrepancies in the density of dislocations calculated from measurements of electrical resistivity and of other properties suggest that stacking faults are produced during plastic deformation. The role of stacking faults is being investigated in α brass, since large concentrations of stacking faults are known to occur in this material.

The energy stored in α brass is much greater than in copper or nickel, and it is released in at least two stages. The high-temperature stage, which is accompanied by marked decreases in electrical resistivity and hardness and an increase in density, is due to the removal of dislocations by recrystallization. At the low-temperature stage more energy is released than at the high-temperature stage, and this is accompanied by increases in hardness and density and a decrease in electrical resistivity. It is likely that these changes during the low-temperature stage are associated with stacking faults and " point " defects such as vacant lattice sites. The possibility that the re-appearance of short-range order is responsible for part of the release of energy in the low-temperature stage is being investigated.

(*d*) *Fatigue and Work Softening.*—The practical importance of the fatigue of metals is obvious. However, the function of the various lattice defects in failure by fatigue is still less clear than is their function in failure under ordinary conditions.

For specimens of copper fatigued at a high stress, the stored energy is released by both recovery and recrystallization, but for specimens fatigued at a low stress considerably less energy is stored, and this is released by recovery only. The results suggest that there are more " loosely bound " dislocations in the high-stress than in the low-stress specimens.

Measurements of the energy stored in fatigued nickel show that the concentration of vacancies here is considerably less than that resulting from unidirectional strains. The results indicate that coalescence of vacancies is unlikely to cause the initiation of fatigue cracks.

The mechanism of " work softening " of a metal deformed under fatigue conditions is also of considerable interest. Determinations of the stored energy, hardness, and X-ray diffraction pattern for copper after 25 per cent. reduction by rolling, and after this reduction followed by fatigue stressing, have been made. Fatigue stressing causes a decrease in the hardness of the as-rolled metal, and this change is reflected in the manner in which the stored energy is released. Further, fatigue stressing causes a sharpening of the X-ray diffraction pattern.

(*e*) *Grain Size.*—The grain size of a metal has long been believed an important factor in determining the mechanical properties of the metal. However, it has been suggested that the number of grains in the cross section of the specimen is the controlling factor and not the grain size itself, and that there could be an effect in α brass but not in copper. An investigation was therefore undertaken into the effect of grain size on the properties of annealed copper and of copper deformed in compression and tension.

The results show that the grain size is itself an important factor in determining the mechanical properties. This has been confirmed by measurements of the stored energy at various deformations for two grain sizes. After equivalent deformation more energy is stored in the fine-grained specimen, and it is released more rapidly and at a lower temperature than in the coarse-grained specimen.

It appears then that grain size is important in controlling both the plastic properties of copper and its annealing characteristics.

(*f*) *Structure of Deformed Metals.*—Measurements of stored energy, electrical resistivity, macroscopic density, and hardness give indirect information about the defect structure of deformed metals. Most direct information is obtained from analyses of the X-ray diffraction patterns of the deformed metal and the changes in these patterns on annealing. Previous work on filings, although avoiding difficulties associated with preferred orientation in solid specimens, was difficult to correlate with measurements of other properties on solid specimens. This difficulty has been overcome by developing a technique for measuring the X-ray diffraction patterns of solid specimens even if preferred orientation is present.

(*g*) *Recrystallization of Zinc.*—The recrystallization of deformed zinc has been studied by a technique which enables this process to be observed as it occurs at elevated temperatures. The growth of new grains is found to be affected by particular features of the deformation process and is extremely variable. Thus average rates of growth which have previously been measured by indirect methods do not represent the true picture.

It has been found that the growth of nuclei to new grains may be completely inhibited by deformation produced during heating and cooling because of the " thermal fatigue " effect discovered some years ago in this Laboratory. This explains some observed anomalies in the behaviour of zinc during recrystallization and indicates that the behaviour of non-cubic metals is sometimes essentially different from that of cubic metals in this respect.

XXII. NATIONAL STANDARDS LABORATORY.

The statutory functions under the *Weights and Measures* (*National Standards*) *Act* 1948 of maintaining the Commonwealth standards of measurement are carried out at the National Standards Laboratory by the Divisions of Metrology, Physics, and Electrotechnology.

During the year the Laboratory has participated in an international intercomparison of resistance thermometers.

The Chief of the Division of Metrology, Mr. N. A. Esserman, attended a meeting of the Comité International des Poids et Mesures and also the inaugural meeting of the Convention de Métrologie Légale.

An officer of the United States National Bureau of Standards spent some weeks in the Division of Electrotechnology in order to become acquainted with new and more precise methods which have been developed for the measurement of small values of capacitance.

Details of the work of the Divisions of Metrology, Physics, and Electrotechnology are given in Chapters XXIII., XXIV., and XXV. respectively.

XXIII. METROLOGY.

1. General.

To ensure complete interchangeability and uniformity of quality and performance in modern engineering production, industry must be able to make accurate measurements. Equipment for this purpose must be regularly calibrated against appropriate working standards. These in turn require periodical calibration in terms of the national standards, certain of which are maintained by the Division of Metrology.

Division of Metrology.—Heavier demands are now being made on the calibration service for balances, weights, volumetric glassware, time pieces, testing machines, and all types of measuring instruments and machine tools. Training facilities have been provided for two Fellows under the Colombo Plan. Lectures have been given to scientific and technical institutions, and on occasions to industrial establishments, and papers were contributed to the Conference on Contemporary Optics. Full advantage was taken of the " Open Days " for a large attendance of the industrial and technical community at the Division. The staff has continued to co-operate with other divisions, Government departments, and universities, and also to act on the Technical Advisory Committee on

Optical Munitions, Standards Association of Australia, National Association of Testing Authorities, C.S.I.R.O./Department of Supply Engineering Group, and other technical committees.

International collaboration is taking place in the study of isotopic light sources and the wavelengths emitted by these sources with a view to selecting a particular wavelength as the ultimate unit of length. The Division recently received a series of electrodeless krypton-86 lamps for these studies from the Physikalisch-Technische Bundesanstalt, Brunswick. International collaboration was also assisted by attendance at a meeting of the Comité International des Poids et Mesures, at the Convention de Métrologie Légale, and at a symposium at the National Physical Laboratory.

2. LENGTH AND ASSOCIATED QUANTITIES.

(Division of Metrology.)

(*a*) *Standards.*—The programme for the maintenance of the national standards of length has continued.

(i) *Line Standards.*—Following upon the work reported in the previous Annual Report, one of the reference metre standards has been recalibrated at the Bureau International des Poids et Mesures at Sèvres. This recalibration has confirmed the instability of this standard. Further intercomparison of this standard with other metre reference standards has shown the necessity for the acquirement of a more satisfactory standard.

(ii) *End Standards.*—The Kösters-N.S.L. interferometer is in regular use. A prototype arrangement of a high-magnification two-jet pneumatic comparator for slip gauges has proved successful in service, and a final design is to be undertaken.

(iii) *Surveying Tapes.*—In order to maintain the highest accuracy in the calibration of reference tapes it is necessary to check the alignment of various features of the 50-metre geodetic base from time to time. This work was carried out during the year, slight adjustments being made where necessary.

Investigations are proceeding into two methods for the determination of the coefficient of thermal comparison of surveying tapes (using the whole tape and not a short length).

A number of tapes have been calibrated for the Department of the Navy, the Snowy Mountains Hydro-electric Authority, the Hydro-Electric Commission of Tasmania, and other bodies.

The final design, and full instructions for the setting up, of equipment for the calibration of working tapes by the States' Departments of Lands has been forwarded to the National Mapping Council.

(iv) *Light Sources and Wavelength Standards.*—Excellent international cooperation exists on the problem of studying various light sources and the wavelengths emitted by them, and the accurate measurement of wavelengths is in progress using mercury-198 and krypton-86 lamps of various types.

(v) *Length Interferometry.*—Experimental work has continued on the setting up of a 24-metre base by interferometry. An interference travelling microscope is being designed and developed. An important aspect of setting up a line standard by interferometry is the ability to set on the lines with high precision, and for this purpose a photoelectric microscope is being developed.

(*b*) *General Interferometry Studies and Associated Research.* (i) *Phase Change Studies.*—Phase change effects at the surface of precision surfaces have been measured by interferometry and correlated with the specular and diffuse reflectance of the surface. This enables the phase change to be evaluated as a length correction from the reflectance measurements. Further exhaustive tests of the correlation will be continued. The use of thin reflecting films of metals and dielectrics is an important factor in many measurements by interferometry, and an important physical property of these films is the change in the phase change at reflection with wavelength.

(ii) *Thin Films.*—Various multi-layer dielectric films have been produced satisfactorily for interferometry projects and for others outside the section. A very wide range of thin films has been deposited for many sections, divisions, and outside departments, and include coatings of aluminium, silver, chromium, bismuth oxide, silicon monoxide, zinc sulphide, and magnesium fluoride.

(iii) *Abrasion Testing of Films.*—The abrasion-resistance qualities of metal and dielectric films deposited by evaporation have been investigated with an abrasion tester and a specially prepared abrasive rubber. An abrasion test specification for metal and dielectric films and bloomed surfaces has been prepared for another department.

(*c*) *Engineering Metrology.* (i) *Measuring and Consultative Service.*—Increased demands have been made upon the Division by industry and other departments for precise measurements over the whole field of engineering metrology. Among specific projects undertaken by the Division were the measurement of large threaded components from a damaged marine diesel engine aboard a motor tanker, and the alignment of a 70-ft. planing machine for the New South Wales Department of Railways and of a 16-ft. horizontal boring machine.

(ii) *Gears.*—A number of gears have been examined ranging from large helical gears used on heavy earth moving equipment, to the small worm gears used in electricity meters. Special equipment is in course of development for measurement of large marine gears.

(iii) *Linear and Circular Dividing Engines.*—A variety of linear and circular scales have been ruled for various internal projects including a number on glass for production by a double evaporation process.

(iv) *Air Gauging.*—In addition to the two-jet slip gauge comparator (*see* Section 2 (*a*) (ii)) a special air gauging unit has been developed for the Division of Electrotechnology. This unit enables the ratio of the diameters of the inner and outer conductors of a precision 50-ohm coaxial line to be determined directly. Progress has also been made with the design and construction of a machine having twin air-gauging heads, for measurements associated with a research project of the Division of Physics. Air gauging has been used for the routine calibration for high accuracy of internal diameters of reference ring gauges, of long bores, and of the cylinders of pressure-gauge testing machines.

(v) *Roundness Measurement.*—The facilities within the Division for the measurement of departures from a truly circular form of cylindrical and spherical surfaces have been considerably improved by the acquisition of a "Talyrond" Roundness Measuring Machine.

(vi) *Lapping Investigations.*—Work has continued on the lapping of thin slip gauges which are flat within a few millionths of an inch in the free condition. Some improvements in technique have made possible the production of satisfactory gauges 0.021 inches thick, but beyond this size the buckling has not been overcome.

In conjunction with the pathological laboratory of a Sydney hospital, work has commenced on the sharpening of microtome knives. A technique has been developed which shows considerable promise of being quicker and more reliable than the method at present in use and which can produce a better edge for certain purposes. A knowledge has been gained also of the manner in which microtome knives wear in use, information which may be of considerable value in the further development of the sharpening process.

3. MASS AND ASSOCIATED QUANTITIES.

(Division of Metrology.)

Increasing demand is made for advice and assistance on graduated glassware and analytical weights and balances. Two Colombo Plan Fellows, one each from Thailand and Indonesia, have spent a period working in the Division to gain experience in the technique of precision measurement in the fields of mass and volume.

(*a*) *Standards of Mass*.—The intercomparison of the reference standards of mass has been commenced, and values obtained for the standards from 1,000 to 50 grams inclusive are based on the mean value of two-kilogram standards which have been compared with the Australian Primary Standard, platinum-iridium kilogram No. 44. An addition was made to the metric standards of mass in the form of a set of integral standards of denomination 20 to 1 kilogram, inclusive, of 25/20 stainless steel.

A 1-kilogram weight of stainless steel was verified to a special order of accuracy for the Dominion Physical Laboratory, New Zealand. A set of weights previously verified in 1951 was recalibrated to a special order of accuracy for the same Laboratory. A set of troy ounce weights was calibrated for use as standards by the Territory of Papua and New Guinea. Comparison was made on behalf of the Government of Victoria of a reference standard pound against the State Primary Standard platinum pound.

(*b*) *Barometric Standard*.—Construction of a long-range reference standard barometer has been completed and employs precision bore tubing. A special McLeod gauge has been made to check the lower points of the gauge barometer. An electronic pressure controller has been developed for use with the barometer calibrating chamber. The system includes the pressure in a large vessel (about 100 litre capacity), to be brought very rapidly to any predetermined value in the range 500 to 800 mm. Hg. The pressure is controlled to within ± 0.01 mm. Hg. over periods up to 2 hr.

(*c*) *Density Measurement*.—A pair of standard plummets has been calibrated over the temperature range 15-25° C. These plummets are the standards used in the measurement of the densities of liquids.

A series of measurements was made of the density of a large single crystal of germanium. The values obtained were consistently different from the accepted value, and further measurements will be made as soon as further specimens can be made available.

In conjunction with the Dairy Research Section, an instrument has been developed for the rapid measurement of the density of opaque liquids in which it is difficult to read an ordinary hydrometer. A prototype instrument has been made and has undergone extensive trials. Work is now in progress on the final design of an instrument suitable for quantity production.

(*d*) *Photogrammetry*.—A theoretical investigation is being made of the relationship between tangential distortion and asymmetrical radial distortion in air survey cameras.

At the request of the National Mapping Council a review has been prepared of definitions used to describe the various metrical attributes of cameras and a rational self-consistent set of definitions compiled. In addition a standard specification has been drawn up for the metrical requirements of cameras to be used for high-precision photogrammetric work.

(*e*) *Time Measurement*.—A portable frequency standard of high stability and with a wide range of facilities was purchased during the year and is undergoing systematic tests.

Developments are being made in the equipment for the regular testing of stop watches.

(*f*) *Measurement of Fluid Flow*.—There is a steady flow of requests being received for this type of work, and where staff and facilities are available an attempt is made to satisfy the demand.

4. APPLIED MECHANICS.

(Division of Metrology.)

The demands for the Division's calibration service for materials testing machines and engineering instruments continued to increase throughout the year, and long delays in meeting these demands are causing concern. One result has been that no development work was possible in the maintenance of the standards.

Some progress was made in the main projects in vibration and machining research and in engineering design analysis, but this was also restricted as a result of satisfying numerous requests for advice and assistance in these fields.

Considerable assistance was received from the Division of Mathematical Statistics in mathematical problems associated with machining research, and from the Defence Standards Laboratory, Department of Supply, Sydney, in metallurgical analyses and reports.

(*a*) *Measurement of the Physical Quantities*. (i) *Force*.—Additional proving equipment ordered includes a 100-ton tension and a 200-ton compression Amsler box and proving rings of capacity 25 ton, 3,000 kg., and 10 kg.

(ii) *Hardness*.—Specially designed scales have been made in the Division to obtain more accurate calibration of the measuring microscope of the Vickers machine.

A report is being prepared on the method developed for measuring an indenter force of 1 kg., and a new design of single proving lever is being constructed for the more accurate measurement of indenter forces up to 150 kg.

In 1953 a method was published by the Division for evaluating hardness numbers from diamond pyramid tests on cylindrical surfaces. A new method has now been devised by extending the theory, and it is planned to investigate the practical application.

The results of the intercomparison tests with overseas authorities on the Rockwell hardness test have shown some discrepancies, mainly attributable to the indenter, which require further investigation.

(iii) *Impact*.—New apparatus has been constructed for the calibration of impact testing machines *in situ*. This equipment, which should make the calibration procedure simpler and quicker, is undergoing tests before being put into service.

(*b*) *Vibration*. (i) *Vibration Isolation*.—The main research activity has been the experimental and theoretical study of the isolation of precision machine tools from external vibration.

Comprehensive tests were made on a seismic block mounting for a large roll grinding machine, having a total load of about 120 tons entirely supported on rubber isolators. The mounting was designed with the general guidance of the Division, and test results to date indicate satisfactory performance.

The site vibration for these tests was produced by several controlled sources, one of which was a mechanical vibrator which produced an unbalanced vertical pulsating force. This was designed and made up to serve the immediate requirements, and is now being redesigned for more convenient general application.

Concurrently, the response to site vibration of the critical elements of an idealized machine tool on a seismic block was investigated theoretically, using an analogue computer, with the co-operation of the Aeronautical Engineering Department of the University of Sydney. A 1-ton seismic block unit has been designed to facilitate closer study of the problem on a laboratory scale.

Two small general-purpose tables for the vibration isolation of sensitive instruments have been further developed in prototype and are being tried.

(ii) *Vibration Measurement.*—Vibration measurements were made on a naval ship during sea trials and site vibration measurements at a mechanized foundry, and several other measurement and testing services were given.

Capacity-type vibration transducers and associated equipment were further developed in the Division, and facilities are now almost complete for two-channel recording with a vertical and a horizontal transducer in each channel.

(iii) *Dynamic Balancing.*—A paper was published on the calibration of dynamic balancing machines by an extension of a three-mass technique published previously.

(iv) *General.*—A number of demands for vibration services have been satisfied, and numerous enquiries answered. These have seriously impeded the main research projects.

A lecture on vibration isolation was given to the Institution of Production Engineers, Sydney, in August, 1956, and in December to a technical conference of an industrial firm.

(*c*) *Engineering Design Analysis.* (i) *Design Techniques.*—The emphasis throughout the year has again been on the teaching of this subject. Three short talks, suitably illustrated with film strips, were used on several occasions during the year to introduce the subject to engineers.

A series of lectures was given by invitation throughout the third term of 1956 to fourth year engineering students of the University of Sydney.

The Section also cooperated with the University of Melbourne in a series of six lectures entitled " Geometric Analysis of Engineering Designs " arranged by the Extension Committee in February-March, 1957.

Papers are being prepared to show the basic techniques developed for geometric analysis and for the setting up of local basic engineering standards in industrial firms.

(ii) *Process Variability.*—The investigation was continued on the tapping of 7/16-UNF-2B nuts on bent-shank, automatic-tapping machines in industry. Study is being made of the effect of tap geometry upon the mean size and the variance of the effective diameter of the nuts. The effect of the tapping hole size on the minor diameter is also being studied.

The opportunity was taken during these tests to investigate the relative performance of the British and the American types of " NOT GO " screw plug gauges for unified threads. A report has been prepared on the investigation and submitted to the Standards Association of Australia, the British Standards Institution, the Canadian Standards Association, and the American Standards Association for their consideration.

(iii) *General.*—Other projects included the determination of the optimum dimensions for conduit taps used on a cast aluminium alloy, the variability in drilling SAE1016 steel bushes to obtain a safe allowance for a final boring operation, and the dimensional variability in heat treatment of the same bushes, all for Sydney engineering firms. Information has also been given on design, fits, and tolerances for various purposes.

(*d*) *Machining Research.* (i) *Routing of " Alclad ".*—During the year the investigation was completed on the high-speed routing of " Alclad ", and a paper describing this is now being prepared for publication.

(ii) *Machinability of Australian Materials.*—Construction of the tool life/cutting speed curve for Australian made steel CS1114 has commenced. Further work in this field has included investigations into the influence of microstructure upon the machinability of steels and into the possibiilty of developing reliable techniques for the rapid determination of machinability. These investigations, which include the Schlesinger Index and accelerated tool life tests, are continuing. The two-channel cutting tool force dynamometer, which was constructed last year, has been tried and found satisfactory.

(iii) *Cutting Tools.*—Experiments are proceeding with a new type of cutting tool, called the Kolesov tool, which features a radical departure from the usual geometry of single-point cutting tools and is intended to combine roughing and finishing cuts in the one operation. First results have been sufficiently satisfactory to warrant further investigation. A comparison is being made of the relative machining performance of tungsten carbide and certain ceramic single-point cutting tools.

(iv) *Tool Sharpness.*—An experimental model of the new optical instrument for measuring tool sharpness has been constructed and is now being tried.

(v) *Deep Hole Drilling and Boring.*—The Section has conducted an extensive investigation for a Sydney engineering firm into the machining of tractor bushes made in SAE1016 steel, which is now being produced in Australia. Two independent solutions are being sought by the Division, the one using standard tools and existing facilities in the factory, and the other using specially developed tools and equipment which might have more general application in drilling and boring.

(vi) *The Cutting of Tooth and Bone Specimens.*—The Division has assisted the Faculty of Dentistry, University of Sydney, in the cutting of thin sections of tooth and bone samples without burning or distorting the surfaces by the application of techniques, similar to that developed for cutting slices of germanium, using a diamond-impregnated bronze wheel.

(vii) *General.*—During the year the Machining Group occupied new quarters within the Laboratory, and this has enabled much needed expansion to take place.

Information has been given on a number of topics associated with machining. These included the routing of soft aluminium alloys, the design of a master for producing knurls, the profiling of steel sheets, and the design and manufacture of press tools.

Some preliminary experiments have been carried out on a special bar turning machine to determine the optimum tool geometry and cutting conditions for the turning of CS1055 steel.

A lecture was given on various aspects of machining research by a member of the staff in December, 1956, to a technical conference of an industrial organization.

XXIV. PHYSICS.

1. General.

The Division of Physics, which is one of the Divisions of the National Standards Laboratory, is responsible for the maintenance of the standards of measurement in heat, light, and related fields and the calibration of precision instruments for scientific and technological purposes. It is also carrying out basic research in several fields, the most important of which are studies of the properties of metals at very low temperatures, the study of optical image structure, the optical properties of diffusing media, and solar phenomena.

This Chapter describes the work of the Division of Physics. The Division's work in solar physics is described in Chapter XXVIII., Section 2.

Division of Physics.—An intercomparison of resistance thermometers was successfully completed during the year as part of a project in which several national standards laboratories co-operated.

The electrolytic condensation hygrometer developed in the Laboratory has fulfilled its early promise, and studies have been made of the basic physics of the crystal surface. The essential design features of an instrument of wide application have been worked out in the expectation that commercial production of the instrument will shortly commence.

Research work at very low temperatures has been extended to include studies of paramagnetic resonance, a phenomenon which holds possibilities of great practical importance.

Late in the period under review a solar observing station at Fleurs, some 30 miles west of Sydney, was brought into operation. In spite of the low altitude, the quality of the photographic records obtained when seeing conditions are good closely approaches theoretical limits imposed by the aperture of the present optical equipment. (This work is reported in Chapter XXVIII, Section 2.)

Plans have been made, and staff trained, for participation in the programme of the International Geophysical Year as regards solar observations.

Very satisfactory progress has been made in the experimental and theoretical study of the diffusion of light by scattering media, and it is gratifying to record the continued financial support of this project by C.S.R. Chemicals Proprietary Limited.

The work of the Division has been recognized by invitations to members of the staff to attend overseas conferences. Dr. P. G. Klemens was Visiting Professor at the National Research Council of Canada. Dr. W. H. Steel attended a Symposium on Communication Theory and Antenna Design at Boston University arranged by the United States Air Force. Mr. J. T. Jefferies is collaborating in studies of solar phenomena with the staffs of Harvard College Observatory and Sacramento Peak Observatory, Colorado. Mr. J. V. McAllan was awarded a short-term Fellowship for studies at Massachusetts Institute of Technology. These visits are of great value as they enable members of the staff to meet fellow workers abroad and become acquainted with trends in their own fields in other countries.

The Division has representatives on committees of the International Bureau of Weights and Measures, the International Organization for Standardisation, the International Commission on Illumination, the International Astronomical Union, and on a number of local scientific or technical committees.

2. HEAT.

(Division of Physics.)

The principal fields of work in heat are temperature measurement, hygrometry, viscometry, and low-temperature physics. The work includes research, developmental investigations, the maintenance of standards, the measurement of the properties of materials, the calibration of equipment, and the design of special instruments. Much of the work is directly related to the requirements of industry and other scientific establishments.

(*a*) *Measurement and Control of Temperature.* (i) *International Temperature Scale.*—While it is generally agreed that the International Temperature Scale should be extended to temperatures below its present lower limit (90° K.), no satisfactory method of doing this has been devised. With the aim of finding a satisfactory interpolation formula to represent the electrical resistance of platinum as a function of temperature, measurements are in progress down to the boiling point of helium (4° K.).

The results of an international comparison of resistance thermometers at the boiling and triple points of water, arranged by the International Bureau of Weights and Measures, indicate that the Laboratory's realization of these fixed points is in satisfactory agreement with those at other national laboratories.

Improvements have been made in various fixed points used in the realization of the Scale, and photoelectrical equipment for replacing the human eye in assessing a brightness match in optical pyrometry has been developed further.

(ii) *Industrial Pyrometry.*—Many calls continue for the *in situ* testing of temperature measuring equipment used in the industrial heat treatment of metals; 60 installations were examined and numerous requests for the solution of industrial problems in temperature measurement and control were dealt with.

(iii) *Liquid-in-glass Thermometers.*—Work has been continued on the effect of previous thermal history on the response of standard thermometers. Over 250 thermometers were calibrated, many for use to high accuracy.

(iv) *Temperature Control.*—In the design and adjustment of systems for the measurement and control of temperature or humidity it would be advantageous to be able to measure the complex transfer functions associated with control loops; methods of doing this are being examined.

The design of a pressurized system for the expansion of carbon dioxide has given a more steady and efficient means of providing cooling than is obtained with the usual expansion system; the new system has found applications in the cooling of condensation hygrometers, low-temperature baths, and in an expansion chamber designed by the Division of Radiophysics for studying freezing nuclei in the atmosphere.

(*b*) *Hygrometry.* (i) *Electrolytic Condensation Hygrometer.*—To determine the potentialities and limitations of this hygrometer which employs as its sensitive element a water-soluble ionic crystal, the basic processes which occur on the surface of the crystal have been studied. In addition to providing a semi-quantitative explanation of the behaviour of elements, fundamental information has been gained on the properties of very thin films of saturated solution and on the energetics of crystal growth and dissolution. It has been confirmed that at ordinary temperatures an absolute accuracy of 0.01° C. in the equivalent dew-point is readily obtainable, and that the hygrometer is both convenient and capable of very rapid response.

The new hygrometer, for which patent rights have been granted, is expected to have application to a wide variety of industrial and technical problems. Hygrometers specifically designed for use as standard reference instruments are under construction. In addition both manually and automatically operated versions of the hygrometer are under development for commercial production, the basic designs having been selected to give instruments which will cover a wide temperature range and have a rapid response.

(ii) *Probe Hygrometer.*—A common problem is the measurement of humidity in a microenvironment such as the determination of humidities in the vicinity of herbage or in the wool on a sheep's back. For such measurements a " probe " is required, but even the best available suffer from instability of calibration. To overcome this difficulty a simple calibrating unit is being developed which will be suitable for use in the field. Probe elements of anodized aluminium, as developed elsewhere, have been adapted for use in the technique.

(*c*) *Viscometry.*—The falling sphere viscometer has been modified to make it suitable for measurements on opaque liquids of high viscosities, and experimental viscometers have been constructed with helical capillaries 100 cm. long. Work is proceeding on the construction of apparatus with which it is hoped to make viscometric measurements accurate to a few parts in 10,000.

(*d*) *Specific Heat Measurement.*—There has been an increase in the industrial demand for the measurement of the specific heats of materials, which has required the development of facilities for such work.

(*e*) *Low-temperature Physics.* (i) *Low-temperature Research Facilities.*—The liquid helium plant has operated very satisfactorily and has met the increasing demand for liquid helium for the production of very low temperatures for research purposes.

A large electromagnet capable of providing a field of 16,500 gauss, constructed in the Laboratory's workshops, has been brought into use. A control circuit for field stabilization to a few parts in 10,000 and other ancillary equipment are under construction.

An air liquefier has been installed to supply the liquid air requirements of the National Standards and Radiophysics Laboratories.

(ii) *Conduction Phenomena in Solids.*—Experimental and theoretical work is continuing on thermal and electrical conductivities of metals and alloys at very low temperatures. Thermal measurements are being made on different types of solid to identify types of imperfection present and to ascertain more fully the effects of various agents on the crystal structure. Measurements with selected copper alloys have revealed markedly different effects in the different alloys.

Further theoretical studies on the scattering of electrons and lattice vibrations by crystal imperfections have confirmed the results of previous investigations on dislocations and have explained the large effect of stacking faults on the electrical resistance of some plastically deformed metals.

(iii) *Specific Heat.*—Further studies of the specific heats of metals and alloys have been made, particularly of the transition metals, nickel, iron, and cobalt, and of copper and various copper alloys.

(iv) *Temperature Measurement.*—A new cryostat incorporating a liquid helium to liquid hydrogen converter is in use for the realization of the boiling point of hydrogen, the calibration of secondary temperature measuring equipment, and studies on resistance thermometers of platinum and carbon in the range 4–90° K.

(v) *Ultraviolet Absorption Spectra.*—In collaboration with the Physical Chemistry Department of the University of Sydney, an optical cell for use at liquid helium temperatures has been developed for the study of ultraviolet absorption spectra.

(vi) *Paramagnetic Resonance.*—Measurements of the absorption of microwaves in matter subjected to a magnetic field can yield valuable information on ionic and nuclear structure and on the fields present in the crystal. For the most useful results it is generally necessary to cool the substance to low temperatures. Paramagnetic resonance measurements also have a direct bearing on techniques for obtaining very low temperatures. The possibility of using this phenomenon in the design of a revolutionary microwave amplifier of exceptional sensitivity has recently been suggested; such an amplifier would be of great practical importance.

Work in this field has been commenced by measurements at room temperatures on a complex chromium salt and by the construction of apparatus suitable for use at low temperatures.

3. LIGHT.

(Division of Physics.)

The Light Section embraces activities in photometry, optics, and solar physics. It is responsible for the maintenance of the various photometric standards for measurement, for undertaking calibrations and precise measurements, and for providing technical guidance in the fields of photometry, colorimetry, and optics.

The Section's main research interests relate to the optical properties of diffusing media, the structure of optical images, and the physical processes operative in the outer layers of the Sun. The latter project has been possible only because of the Laboratory's facilities for designing and constructing highly specialized optical equipment which could not be acquired otherwise. Very encouraging results are beginning to appear from the Division's new solar observing station at Fleurs, some 30 miles west of Sydney.

(*a*) *Photometric Standards.*—The Laboratory maintains standards of physical measurement of luminous intensity, luminous flux, and colour temperature, and is equipped to make measurements in terms of these standards as well as in the fields of spectrophotometry, colorimetry, and radiometry.

A continuous programme of photometric testing and instrument calibration has been carried out on behalf of private industry and governmental institutions. In addition, assistance has been given in response to numerous technical inquiries, especially concerning the physical measurement and control of colour.

(*b*) *Optical Properties of Diffusing Media.*—The products of many industries are essentially optically diffusing media—e.g. paints, pigmented plastics, photographic emulsions, papers, and textiles, though the optical properties of these media are little understood. In particular, their colour control is often difficult. At present there is inadequate scientific basis for understanding the optical properties of these media, so that problems such as colour control can still be tackled only by empirical means.

To provide background knowledge for the physical control of colour in industrial processes, the Division has commenced an investigation of the optical properties of diffusing media. This will provide at the same time experimental tests of the theory of radiative transfer, with extensions to important cases not yet susceptible to theoretical discussion. Experiments are in progress to ascertain the laws governing diffuse reflectance as a function of the scattering and absorption properties of the medium.

One of the main initial difficulties has been to secure reproducible dispersion, or separation, of the scattering and absorbing particles, for the reflectance is dependent on the degree of dispersion. Using as diffusing media suspensions of well-dispersed barium sulphate and titanium dioxide in water, and adding controlled amounts of absorber, excellent agreement has been obtained between observed reflectances and those calculated on the simple basis of isotropic scattering; further experiments in progress are designed to test the usefulness of isotropic scattering concepts for a range of common scattering particles.

(*c*) *Optical Image Quality.*—The performance of an optical system, whether telescope, microscope, or camera, depends on its ability to reproduce object detail in the image. Conventional methods of assessing performance based on resolving power are well known to be inadequate, and there has been in the post-war period an extensive study of optical image structure. One of the main approaches has been through the contrast transfer function, which expresses the contrast reduction from object to image for each detail size in the object.

Theoretical investigations of image formation in terms of the contrast transfer function have been made in the Division, and recent studies of the effects of small aberrations have led to a rediscussion of aberration tolerances, which form the basis of assessment of all optical designs. As a result, tolerances can now be allocated both to systems such as telescopes or cameras which use incoherent illumination and to those such as microscopes or projectors which use partially coherent illumination.

Methods of testing instruments by measuring contrast transfer functions are also under development.

(*d*) *Solar Physics.*—This work is described in Chapter XXVIII., Section 2.

4. NUCLEAR STANDARDS.

(Division of Physics.)

Work is in progress in the Division to redetermine the gyromagnetic ratio of the proton, a constant which is important for atomic physics and also as a basis for the measurement of magnetic fields to a high degree of accuracy. As much of the equipment necessary for this work is applicable to the determination of the energy of alpha particles from radioactive substances, a redetermination is being made of the energies of certain standard alpha particle groups.

5. ELECTRONICS.

(Division of Physics.)

The Electronics Section has provided very important and valuable assistance in various researches in progress in the Division.

For the rapid exploration of magnetic fields an integrating amplifier and recording system has been designed and built which is based on the conventional search coil-flux meter method. For accurate point-to-point measurements of strong magnetic fields, equipment based on the nuclear magnetic resonance of the proton has been constructed. For the solar telescope at the Fleurs Field Station, guiding mechanism has been constructed which uses signals detected photoelectrically from four points on the Sun's limb.

The contrast transfer function method of testing the quality of optical systems treats optical components as analogues of electrical filter networks. Equipment is under construction for the measurement of the relative phase and amplitude of the emergent light when the optical system under test is scanned by a beam of light modulated at a varying frequency.

XXV. ELECTROTECHNOLOGY.

1. GENERAL.

Much electrical work, particularly in electronics, is undertaken in Divisions and Sections as an integral part of research in other fields of investigation, but the Organization's research on electrical measurements and standards and on electrotechnology is carried out within the Division of Electrotechnology, which is part of the National Standards Laboratory (*see* Chapter XXII.).

The Organization also collaborates with the Electricity Supply Association of Australia in encouraging electrical research within the universities through its Electrical Research Board (*see* Section 8 of this Chapter).

Division of Electrotechnology.—The Division of Electrotechnology is responsible for the maintenance of the Commonwealth standards of measurement of electrical quantities. It also maintains the Commonwealth standard of measurement of frequency in conjunction with the Commonwealth Observatory, Mt. Stromlo, and other standards derived from frequency, resistance, and electromotive force. The Division undertakes electrical and magnetic measurements on materials, and the calibration of instruments and equipment such as resistors, bridges, potentiometers, capacitors, inductors, indicating instruments, instrument transformers, signal generators, wavemeters, and fluxmeters. Research is being continued to improve and extend the electrical measuring and standards facilities, and on the dielectric properties of insulating materials and the microwave spectra of gases.

Dr. F. K. Harris, of the National Bureau of Standards, United States of America, spent some weeks in the Division studying the special techniques that have been developed for the measurement of small capacitors.

The Division accepted an invitation of the Faraday Society to give an account of some of its dielectrics research work at a conference held in Amsterdam, and Dr. Dryden presented a paper on the dielectric properties of alkali halides.

Mr. B. V. Hamon, who has for some years been concerned with the development of special instruments for measuring the physical properties of sea-water, has transferred to the staff of the Division of Fisheries and Oceanography.

One of the special 1 to 100 ohm " build-up " resistors developed by the Division was presented, on behalf of the Commonwealth Government, to the Bureau International des Poids et Mesures.

2. DIRECT CURRENT.

(Division of Electrotechnology.)

Absolute determinations of the primary electrical units, the ohm and the volt, in terms of the metre, kilogram, and second are made at infrequent intervals of ten years or more. The actual standards take the form of resistance coils and standard cells which must be sufficiently stable to preserve the units during the intervening years.

To lessen the effect of individual instabilities each national laboratory relies on the mean value of a group of resistance coils and standard cells. Steps have been taken to enlarge the Australian primary groups, and some of the most stable coils have been sent overseas to be checked against the standards of other nations.

The procedure for intercomparing the members of the Australian groups has been critically reviewed. Improvements in measuring techniques and galvanometer sensitivity have been introduced and enable the resistance coils to be intercompared now to one part in 10,000,000.

Some of the coils have exhibited an unusually rapid change of resistance with time. This has been shown to be due to defective sealing of the container. In the worst case corrosion of the resistance wire was quite evident, and very marked improvement in performance resulted from cleaning the wire and hermetically sealing the container. Other coils showing evidence of poor sealing are being cleaned and resealed.

The special 1 to 100 ohm " build-up " resistor described in previous reports has proved very accurate and convenient. A similar unit for the range 100–10,000 ohms is now being developed.

3. POWER FREQUENCY.

(Division of Electrotechnology.)

(*a*) *Protection Current Transformers.*—The Standards Association of Australia is at present revising the specification for protection current transformers, and the Division has conducted some experimental work to check the validity of some of the indirect tests in the old specification when applied to the various types of transformers. The results show that the tests are valid only for some of the transformers and therefore must be used with caution.

(*b*) *Calibration of Current Transformer Testing Sets.*—An electronic meter has been developed which indicates directly the errors of the set under test and avoids any further calculation. In the case of certain instruments this has meant a saving of several weeks of calculations per instrument.

(*c*) *Compensated Voltage Transformer.*—A 1100/110 V voltage transformer has been developed with error compensation over wide ranges of burden, operating voltage, and frequency. The errors remain within 0.01 per cent. for the following variations: burden 0-5 VA, a 10:1 range of voltage, and a 2:1 range of frequency.

(*d*) *High Voltage Testing.*—A measuring spark gap has been developed for peak voltage measurements up to 140 kV. Crossed cylinders are used instead of the more conventional spheres. The gap is not only easier to manufacture but is much less sensitive to nearby objects. Only one calibration is required for D.C. of either polarity, A.C., impulse voltages, and for grounded or insulated electrodes. The maximum field strength between crossed cylinders has been calculated, and the puncture strength of air for this electrode configuration has been deduced.

Two means of preventing excessive pitting of measuring spark gaps have been developed. The first method uses a high series impedance, arranged to be free of corona and guarded, which also prevents interruption of the supply. In the second method a trigatron type of gap is connected in parallel to the measuring gap. This auxiliary gap is triggered by the breakdown of the measuring gap and diverts the main discharge current from the latter.

The surge voltage distribution of locally made transformers has been investigated and has resulted in an improved performance under impulse conditions.

The methods of corona detection described in previous reports have found several additional applications including the quality control of television components.

4. AUDIO AND RADIO FREQUENCY.

(Division of Electrotechnology.)

(*a*) *Calculable Capacitor and Absolute Determination of the Ohm.*—The characteristics of the new type of calculable capacitor mentioned in the previous Annual Report have been carefully studied both from a theoretical and experimental viewpoint.

A prototype of one form of this symmetrical type of capacitor was constructed and a very thorough investigation made of its sensitivity to departures from the ideal symmetrical geometry. The performance was most satisfactory, and a very precise capacitor is being constructed on the same principle. The capacitor consists of four separately insulated cylindrical bars mounted parallel to each other in an external cylindrical shield. The effective length of the capacitor is determined by the separation of two metal shield tubes which are inserted from each end along the axis of symmetry. This separation is measured directly in terms of optical wavelengths by means of an interferometer system, and the change in capacitance as one of the tubes is moved is calculated from the change in separation as measured by the interferometer. The maximum change in capacitance will be 0.25 pF, and the present design should enable this to be computed with a precision of 1 in 10^7. All parts for the capacitor have been completed, and tests are in progress on partial assemblies of the unit.

A number of very stable components and precision measuring assemblies are necessary to enable the 1-ohm resistance standards to be measured in terms of this calculable capacitor, and steady progress has been made in the development of these units. One problem inherent in the system is the transfer of resistance values from D.C. to A.C., and a very precise bridge has been constructed to determine the relative frequency characteristics of various types of resistors.

(*b*) *Detectors for A.C. Bridges.*—A very sensitive detector is required to obtain the desired precision of measurement with such a small calculable standard, and a number of valve types and circuit arrangements have been investigated with a view to obtaining the maximum sensitivity. A detector embodying the results of this work has been constructed, and an overall improvement in sensitivity of about 4:1 was obtained.

(*c*) *Production of Uniform Straight Cylinders.*—The final machining of the cylindrical bars for the calculable capacitor was accomplished by a self-generating process which yielded a uniformity of diameter of a few microinches from bar to bar. The brass bars are first turned between dead centres to produce true solids of revolution. The final cut is then made with a diamond tool mounted on a close-fitting sleeve bearing. The centring forces of the bearing are much greater than the cutting forces involved, and consequently a very straight uniform cylinder is generated. Such a technique is equally effective in the generation of internal surfaces and should find many applications in precision engineering.

(*d*) *Electromagnetic Controls for Interferometer Plates.*—The optical interferometry involved in the calculable capacitor requires that continuously variable fine controls both of the translation and of the tilting of the interferometer plates should be available, preferably under vacuum. Special electromagnetic controls have been developed for this purpose. Their stability and performance generally has been extremely satisfactory, and they have proved of considerable value in other interferometry applications in the Laboratory.

(*e*) *Conductivity of Electrolytes.*—By using a tube containing the electrolyte as a loop coupling two transformers it is possible to make conductivity measurements without any electrodes in the solution. Assistance was given to the Faculty of Agriculture, University of Sydney, in constructing such a system for conductivity measurements on milk. The results were very satisfactory, and further units are to be constructed.

(*f*) *Low Resistance Switches.*—The variation of the contact resistance of switches is an important limitation to many pieces of measuring equipment. A bridge for the measurement of small resistances was constructed, and tests have been made on a number of commercial switches and contact assemblies. A prototype switch was constructed in which the resistance variation was only a few microohms.

(*g*) *Frequency Measurements.*—Equipment for receiving the 16 kc/s transmissions from Rugby, England, has been constructed. The frequency of these transmissions is controlled by a very stable oscillator and is measured daily at the National Physical Laboratory against a caesium atomic standard. The beat frequency of about 1 cycle per 10 minutes between the received signal and a 16 kc/s derived from our own standard is recorded. Measurements indicate that frequency comparisons to 1 in 10^9 are possible and that even higher precision may be obtained when more is known about the variation of the transmissions with time of day and throughout the year.

Improvements have been made in microwave frequency measuring equipment. A multiplier stage (810 Mc/s to 2,430 Mc/s) has been added to increase the power available for measurements at the extreme high frequency end of the range. A locked oscillator has also been introduced into the frequency multiplying chain at 10 Mc/s in order to improve the phase stability of the signal.

(*h*) *Conductance Standard for Very High Frequencies.*—The greater use of very high frequencies for services such as television and navigational aids has created a demand for the corresponding basic standards of measurement. One of the most important quantities to be measured is the impedance of the various transmission circuits and components. Several commercial impedance measuring equipments are available, for the standardization of which it is necessary to set up calibrating apparatus of higher order of accuracy. At these frequencies it is not possible to derive precise impedance standards from the 1-ohm resistors maintained at direct current, nor from low-frequency standards. Such standards must be based on the known properties of co-axial lines made with sufficient mechanical precision, and with the use of metals of adequate conductivity. Standards of this type are under development. Precise air gauging equipment has been developed by the Division of Metrology to check simultaneously the inner and outer conductors of a co-axial line and to indicate departures from the nominal ratio of the two radii.

(*i*) *Power Measurement at High Frequencies.*—Bolometric methods of power measurement for the microwatt and milliwatt ranges are being developed for wider ranges of frequency with improved accuracy. The immediate application for these methods is the direct determination of the power output of standard-signal generators.

(*j*) *Voltage Measurement at High Frequencies.*—Precise capacitor dividing networks have been developed for use with thermocouple instruments to extend the range of voltage measuring facilities in the Division. Voltage measurements up to 1,000 volts and up to a frequency of 100 Mc/s can now be made.

(*k*) *Microwave Spectroscopy.*—The electric field gradient at the position of the deuteron nuclei in heavy water has been determined by measurement of the hyperfine structure, and the smaller magnetic effects occurring in the spectrum are now being examined.

Interest has been directed to the observations of low-*J* transitions of sulphur dioxide falling in the *X*-band region, which have not previously received attention. In the case of molecules containing the sulphur-33 isotope the hyperfine structure arising from the nucleus has been resolved and measured.

(*l*) *Random Noise.*—The investigation, initiated last year, of the effects of random voltages in non-linear networks is being extended. Attention has been focused mainly on methods of obtaining probability distributions for the voltages and currents in such networks. While purely theoretical methods have been successful in a few cases, the majority of networks of interest have proved to be extremely resistant to this type of attack. Consequently the investigation is now being augmented by experimental methods for which purpose a new, purely electronic instrument has been devised. This instrument automatically obtains and presents the probability distribution of any voltage connected to its input terminals.

5. Magnetic Measurements.

(Division of Electrotechnology.)

Equipment has been built to trace automatically hysteresis loops of magnetic material on an X-Y recorder. A single strip tester has also been developed for use in conjunction with the hysteresis loop plotter for testing small samples. This facilitates investigation of anisotropic properties of magnetic materials, particularly after heat treatment in a magnetic field.

6. Dielectric Investigations.

(Division of Electrotechnology.)

In the dielectrics research for the past year the emphasis has been chiefly on the effect of crystal imperfections on the dielectric properties of solids, both organic and inorganic. Some work has also been continued on liquids.

A theoretical investigation has been made on problems related to superconductivity in metals.

(*a*) *Alkali Halides.*—An investigation has been completed of the dielectric properties of the fluorides, chlorides, bromides, and iodides of lithium, sodium, and potassium containing divalent cation impurities, and from the results, the energy barriers to the movement of the cations have been determined. The energy barriers have also been calculated on the basis of a model of solid spherical ions with the same elastic properties as the bulk material. Remarkably good agreement with the experimental values has been obtained.

(*b*) *Effect of Crystal Imperfections on Dielectric Properties of Long-chain Compounds.*—Previous work on long-chain compounds has shown that their dielectric properties are partly determined by crystal imperfections. In order to detect any effects due to impurities several esters have been vacuum fractionated in a spinning band distillation column and the dielectric properties of the various fractions determined. The results show that the dielectric loss is smaller in the middle fractions, which would be expected to be more pure.

In each fraction the dielectric absorption is wider than a Debye curve and can be interpreted as the sum of two such curves. Both components are larger in the impure material but show no difference in the frequencies of the maxima. Only one component is sensitive to plastic deformation, which gives a larger effect in the more impure material.

(*c*) *Multiple Relaxation Times in Liquid Solutions of Hindered Hydroxy Compounds.*—From theoretical work on solutions Budo predicted that, under certain conditions, solutes having polar groups capable of rotation independently of the main part of the molecule would exhibit more than one relaxation time. Until recently this had not been observed experimentally. However, work in this laboratory during the past year has demonstrated that in decalin solutions of each of the hindered hydroxy compounds *tricyclo*hexylcarbinol, 2:4:6-tri-t-butylphenol, and 4-bromo-2 : 6-di-t-butylphenol, two separate dielectric absorption maxima are obtained, corresponding to two relaxation times. The results show that, in each case, one absorption is related to the rotation of the whole molecule and the other to the rotation of the hydroxyl group.

(*d*) *Wool Wax as an Impregnant for Paper Capacitors.*—In previous work it was found that refined wool wax gives fairly low dielectric loss and has a relative permittivity of 3.2, compared with a value of only 2.1 for petroleum jelly. It appears, therefore, that wool wax could possess an advantage over petroleum jelly as an impregnant for paper capacitors. During the past year experiments have been carried out in collaboration with Ducon Condenser Ltd. on the application of wool wax as a capacitor impregnant. It was found that wool wax gave 10-20 per cent. larger capacitance than petroleum jelly and at the same time appeared reasonably good with regard to dielectric loss, insulation resistance, and dielectric breakdown strength.

(*e*) *Dielectric Breakdown in Alkali Halides.*—An appropriate method has been devised for dealing with multiphonon ionization and recombination processes between isolated levels and conduction levels in alkali halides. This has led to a quantitative theoretical treatment of the high-temperature dielectric breakdown of these crystals. Since relevant experimental work is scanty, high voltage gear has been constructed with a view to determining whether the breakdown process envisaged is in fact true, and also to investigate the effect of extraneous factors such as the material of the cathode.

(*f*) *Superconductivity in Metals.*—It is basic to the theory of metals that the normal modes of the lattice motion are sufficiently well described for all non-dissipative processes by quantized elastic waves. On the supposition that this holds in the presence of conduction electrons, a treatment of the electron lattice interaction has been given which neglects only its effect on the anharmonic motion and is otherwise exact. Taking this as a model, further work has been done on the problem of superconductivity.

(*g*) *Helium II.*—The validity of a Boltzmann rate process formula for a Bose gas has been critically examined and questioned. In this connexion it has been shown that certain conventional methods for dealing with problems of the superfluidity of helium II are open to doubt.

7. Special Investigations.

(Division of Electrotechnology.)

Equipment for Bore Hole Logging.—Continuing the investigation for Enterprise Exploration Pty. Ltd., complete equipment has been built and tested in the Laboratory to enable field trials to be carried out shortly. The bore-hole probe unit, consisting of Geiger Müller tube, associated circuits, pulse transmitter, and transducer, is accommodated in a tube 11 feet long and of 1¼-in. bore.

8. Electrical Research Board.

The general objective of the Electrical Research Board is to foster fundamental electrical research in universities and the training of graduates in research methods. Grants are made for projects suggested by the universities.

The Board is representative of the Electricity Supply Association of Australia, the universities, and the Organization. Financial support from member organizations of the Electricity Supply Association has enabled the Board to support investigations in most of the universities of Australia.

Investigations on the stability of power supply systems are being continued in the University of Adelaide with projects on network analysers and in the University of Melbourne by using model machine techniques. Transients are being studied in the University of Tasmania. In the University of Queensland work has been completed on the construction of the impulse generator and ancillary measuring and recording equipment; substantial progress has been made on thunderstorm studies and the preparation of an isoceraunic map. Work has been continued on the project on the dynamic stability of alternators. The New South Wales University of Technology has also continued the project on the representation of synchronous machines by electric models. Investigation of the loss of electrode material from hot spots in electric arcs is being continued in the University of New England.

XXVI. RADIOPHYSICS.

1. General.

The techniques of radio and particularly its more recent offshoot, radar, have found employment in an ever-widening field of both scientific and industrial application. The use of pulse methods and the exploitation of very much higher frequencies than was possible a decade ago have provided scientists with new research tools of surprising versatility and power. The Division of Radiophysics is organized to carry out investigations in fields in which modern radio techniques have particular application. Chief among these are fundamental researches in cloud and rain physics and radio astronomy—fields in which it has already established an international reputation. The Division is also concerned with the study of physical properties of semi-conductors, and especially the devices known as "transistors" which are initiating a major revolution in electronic techniques, and some aspects of radio navigation and of the propagation of radio waves.

The Organization's researches on the propagation of radio waves under the direction of the Radio Research Board date back a long way in the history of radio and have contributed much to the understanding of fundamental conditions and processes in the ionosphere. The Board, which was established in 1927, co-ordinates the researches of a group of permanent C.S.I.R.O. officers at the Radio Research Laboratories with allied investigations in the services, the Postmaster-General's Department, and the universities. It fosters approved projects in the universities where staff and student interest exists. Liaison between the various bodies carrying out research in the radio field and those who make use of the results of this research is facilitated by a Consultative Committee on Radio Research.

The work of the Division of Radiophysics is outlined in Sections 4, 5, and 6 of this Chapter and in Chapter XXVII, Section 8, and Chapter XXVIII, Section 3. That of the Radio Research Laboratories is described in Section 7 of this Chapter.

Division of Radiophysics.—There have been no major changes in the research programme of the Division, which is predominantly engaged in basic and applied investigations in the field of rain and cloud physics, and fundamental research in radio astronomy.

The Division's investigations into the possibility of increasing rainfall by seeding clouds with silver iodide from the air have proceeded a stage further with the initiation of a second carefully planned field experiment. This trial, which is being carried out in South Australia, and that already in progress over the Snowy Mountains, are designed to provide a conclusive answer as to whether rainfall may be increased by artificial means in typical areas of Australia and if so, by how much.

Highlights in radio astronomy have been the completion of a survey of the distribution of neutral hydrogen in our Galaxy, and the bringing into operation of new equipment of high resolution designed for studying high-intensity radio radiation from the Sun. The final design for the proposed giant radio telescope is awaiting the outcome of a design study being made by Messrs. Freeman, Fox, and Partners in England.

A symposium on "Radio Astronomy" was held in September, and a symposium on "Meteors, Dust, and Rainfall" in May, both of which were attended by a number of distinguished visitors from establishments in Australia and overseas.

Dr. J. H. Piddington attended an international conference in Stockholm in August and visited radio astronomy centres in Europe and the United States of America. Dr. L. W. Davies was invited to deliver a course of lectures before the U.N.E.S.C.O. Symposium on "Semi-conductors and Microwave Techniques" at New Delhi, India, in November. Mr. F. J. Kerr attended a conference arranged by the International Astronomical Union in Stockholm in June, 1957, and Mr. J. P. Wild completed an extended visit, made in an advisory capacity, to several radio astronomy research centres in the United States.

Radio Research Laboratories.—The research programmes of the two laboratories at Camden and Sydney for the study of the ionosphere have been pursued without major charge. Information obtained from observational and theoretical studies of this highly electrified region of the atmosphere continues to have practical application in improving the efficiency of radio communication. It is of interest also that ionospheric data have become of increasing importance in relation to meteorological studies and problems associated with rocket flights.

The Laboratories are preparing to take part in the forthcoming world-wide programme of observations during the International Geophysical Year. For this purpose valuable equipment has been made available on loan from scientific establishments in the United States of America.

This comprises a spectrophotometer for studies of air glow, and "backscatter" equipment operating on three fixed frequencies with rotating directive antennae, to obtain information on sporadic *E*, the aurora, meteor ionization trails, and the variations in regular ionospheric layers, including travelling disturbance movements.

Two scientists from America assisted officers of the Organization to install this equipment. Mr. Meyhill of the United States National Bureau of Standards visited Camden to assist with the spectrophotometer; and Professor Peterson of Stanford University assisted with the backscatter set.

Laboratory and other accommodation at Camden have been further improved during the year, and a small staff is now in residence.

Grateful acknowledgement is made to all those individuals and establishments outside the Organization who have assisted with the work of the Laboratories.

2. Cloud and Rain Physics.

(Division of Radiophysics.)

This work is reported in Chapter XXVII., Section 8.

3. Radio Astronomy.

(Division of Radiophysics.)

This work is reported in Chapter XXVIII., Section 3.

4. Radio Propagation.

(Division of Radiophysics.)

The Division is represented on the Consultative Committee on Radio Research which brings together the principal organizations in Australia using radio communications and those engaged in radio research, for the purpose of obtaining co-operative action towards the solution of problems arising in the use of radio communications. During the year the Division has been engaged on two such co-operative investigations.

(*a*) *Radio Noise Levels.*—The survey of radio noise levels throughout Australia at the wavelengths used for broadcasting and for high-frequency communication, which was referred to in last year's report, is continuing. By stationing each set of the measuring equipment at a particular place for a period of approximately two years, and then moving it to another site, it is planned to obtain useful information on the noise levels at a considerable range of locations throughout Australia and the islands to the north, within a reasonable period of time.

During the present year one such transfer was effected from a site in Victoria to one in Queensland, and preliminary preparations were made for a second, from Western Australia to New Guinea.

Another phase of this work is concerned with the provision of information on the directions of arrival of thunderstorm noise, with the aim of making it possible to specify the relationship between the expected noise levels on radio antennas of different types at a given site. During the current year two series of observations bearing on this problem were carried out and preparations for two more are almost complete.

(*b*) *Communication Anomalies.*—Unexplained nighttime failure of communication between civil aircraft and ground stations in 1954, particularly in the Northern Territory, was reported by the Department of Civil Aviation. The aircraft were using frequencies (around 3 Mc/s) when, according to ionospheric predictions, communication conditions should have been excellent. As a result, a joint investigation of the phenomena, co-ordinated by this Division, was carried out over the greater part of 1956. However, there was no evidence of the type of anomaly encountered in 1954, and it is very likely that the improvement in ionospheric propagation is due to the increase in solar activity from its minimum in 1954. If so, no further trouble should be experienced until about 1963, when sunspot numbers will again be low. However, the Department of Civil Aviation is keeping a watch for the recurrence of anomalies, and should they occur earlier, their speedy investigation has been planned.

5. Radio Navigation.

(Division of Radiophysics.)

Work is continuing on the development of a method for obtaining bearing from existing Distance Measuring Equipment (D.M.E.) beacons. Equipment for mounting in an aircraft has been completed, together with a ground station and aerial system, to simulate the D.M.E. beacon. It is proposed to set up the ground station at Kingsford-Smith Airport, and the Department of Civil Aviation has completed the installation of suitable power-supply facilities.

The method using the rotating aerial pattern is still being used, as described in last year's report, but the rotational speed has been reduced to 60 r.p.m. This simplified certain features of the aerial mount design but required additional work on the aircraft instrumentation.

6. Semi-conductors and Transistors.

(Division of Radiophysics.)

Intensive research into the properties and behaviour of materials which are neither conductors nor insulators—and hence are known as semi-conductors—has followed the discovery that devices constructed of such materials —" transistors "—can substitute very effectively for electronic valves in many applications, with substantial economies in space, weight, power consumption, and heat dissipation, together with improved reliability.

The Division is investigating the basic physical properties of semi-conducting materials and the techniques required for producing this material in the various forms and with the characteristics needed for the construction of transistors. In parallel with these studies the application of these devices in electronic circuitry is being investigated.

(*a*) *Semi-conductor Physics.*—Three principal lines of research are in progress:

(i) the growth of semi-conductor monocrystals;
(ii) the properties of junctions between regions of differing conductivity; and
(iii) the development of high-current switching devices.

In addition, some consideration has been given to the possibility of constructing a sensitive semi-conductor amplifier for microwaves (Maser).

Investigations are in progress on the properties of semi-conductor monocrystals grown from melts of pure material, and from solution in elements such as indium. A large vacuum oven for the production of monocrystalline silicon is under construction. The properties of germanium, when deposited as a thin film by evaporation *in vacuo*, have also been investigated; conductivity and Hall measurements indicate the presence of a high density of acceptor centres in all such films investigated. Further work, it is hoped, will yield information on the origin of these centres.

The theory of semi-conductor junction rectifiers, and of other types of junction, has been worked out in more detail. Experiments on units fabricated in the laboratory have shown good agreement with the theory.

The development has been completed of an alloyed-junction p-n-p transistor for high-current (40 A) switching applications, in which the " switch-on " time is as low as 0.5 μsec.

(*b*) *Transistor Circuit Development.*—Following earlier development by the Division of an airborne Distance Measuring Equipment (D.M.E.) using electronic valve techniques, a transistorized D.M.E. is being built to the same specification.

This unit is required to give the pilot of an aircraft a continuous indication of distance to a selected ground beacon. It functions by sending out coded interrogation pulses on a frequency of 206 Mc/s. These trigger the desired beacon which replies on a frequency of 224 Mc/s. The time delay between the interrogation and reply pulses is automatically measured in the airborne set and is converted to an equivalent distance on the pilot's indicator.

Transistor circuits which have been developed to carry out these functions include a double-pulse coding circuit, an automatic time-delay measuring circuit with " memory " facility, a 224 Mc/s superheterodyne receiver, and power convertor and regulator circuits. The only place in which there is no prospect of eliminating valves is in the transmitting oscillator; here the required power level is far beyond the capabilities of 200 Mc/s transistors as presently conceived.

A basic transistor-modulator circuit capable of generating pulses of 1 kW or more peak power has been devised, but as this requires further development it has been decided to assemble an interim D.M.E. using a valve modulator. This will allow the circuits which have been developed so far to be tested under operating conditions. Since a plug-in module form of construction has been adopted, any changes which result from the rapidly developing transistor art can be incorporated with a minimum of trouble.

In this interim stage the D.M.E. will weigh 14 lb. and occupy a space 20 by 5 by 8 in. Its power consumption will be 50 W. These figures are already very much lower than the corresponding ones for the valve-equipped production model, which weighs 45 lb., occupies a space 20 by 10 by 8 in., and consumes 230 W. The ultimate aim is to produce a transistorized unit weighing 10-12 lb. and consuming under 40 W.

Attention is also being paid to changing specifications which are evolving from airline use of D.M.E. Thus by the time transistorized D.M.E. is ready for service it will probably be required to provide more channels and have more transmitter power to give a greater maximum range.

In addition to the above investigations, assistance has been given to other Divisions and to outside organizations in the solution of problems in the application and use of transistors.

7. IONOSPHERE.

(Radio Research Board.)

The investigations at present sponsored by the Board are at Radio Research Laboratories and the Physics Departments in the Universities of Adelaide, Queensland, and Tasmania. Close collaboration is maintained with the Ionospheric Prediction Service of the Department of the Interior and the appropriate activities of the Antarctic Division of the Department of External Affairs. Almost all the research being done under the Board is concerned with the ionosphere, which is the region above the Earth which makes possible long-distance radio communication.

The normal ionosphere is maintained in its ionized condition mainly by radiation from the Sun and therefore shows daily and seasonal variations. These are now reasonably well known for most regions of the Earth. Less is known about the abnormalities, such as ionospheric storms, which disrupt radio communication from time to time, particularly when sunspots are active on the visible solar disk. The method most used for studying the ionosphere involves reflection of radio signals. With techniques now in use it is possible to record ionospheric conditions continuously and also to study disturbances travelling through the ionosphere and the moving ionization trails caused by meteors.

(*a*) *Regular Variations.*—Work has been done at the Radio Research Laboratories on the theory of the anomalous geographical, seasonal, and diurnal behaviour of the F_2 region. A special study has been made of the perturbations of this region by lunar tidal influences.

Special attention has been given to the effects of diffusion of ionization in the F_2 region which has been found to be an important, though not dominant, factor in F_2 behaviour, particularly at night in moderate and high latitudes.

(*b*) *Irregularities and Movements in the Ionosphere.*—The studies of travelling ionospheric disturbances using spaced recorders at Camden, Sydney, and Blaxland and a panoramic variable frequency recorder at Camden have provided much of the most extensive information available in this field. This will be further increased by current investigations of the origin, extent, and nature of these disturbances and by similar observations recently undertaken in other parts of the world. It has also led to the more accurate interpretation of ionosphere records.

A special single-station Doppler equipment was constructed at Adelaide for installation in Antarctica to study upper atmospheric winds using the meteor trail method. The decay time of 800 echoes from meteor trails have been determined in order to obtain information about the physical nature of the diffusion of these trails.

Work on meteor astronomy has continued at Adelaide with radio surveys of meteor showers at 27 and 67 Mc/s to measure radiants and rates, and the level of sporadic meteor activity.

Work has continued in Brisbane on ionospheric irregularities, including a study of (i) lateral deviations of signals from distant stations, (ii) polarization of anomalous echoes, (iii) effects near penetration frequencies.

Ionospheric drifts have also been studied in Brisbane from fading analyses. A system has been worked out, and equipment constructed for the automatic determination of all drift parameters using magnetic tape recorders and electronic correlators.

(*c*) *Magnetic and Ionospheric Storms.*—Magnetic and ionospheric storms have been the subject of further study by the Laboratories. On the basis of this theoretical work, practical steps have been taken by the Ionospheric Prediction Service of the Department of the Interior to produce a prediction chart for disturbed periods which is likely to be of value to organizations engaged in long-distance communications.

(*d*) *Whistling Atmospherics.*—Three "whistler" recorders have been constructed in Brisbane and in addition an analyser has been made for determining frequency-time relationships. The study of whistlers is an important part of the International Geophysical Year programme, and the University of Queensland is at present co-operating with laboratories in Japan so that a co-ordinated study may be made of this phenomenon.

XXVII. ATMOSPHERIC PHYSICS.

1. GENERAL.

Weather and climate make their impact on many phases of human activity, and meteorology, besides providing innumerable avenues for study as a physical science, is a public utility. As such it provides a wide range of services, but these can prosper only on a foundation of basic research into the many problems yet unsolved.

The Organization is undertaking a number of basic studies of the physics of the atmosphere with the object of obtaining a more fundamental knowledge of the weather and the processes which control it. The work of the Division of Meteorological Physics is directed towards a better understanding of the behaviour of the atmosphere with a view not only to improving the prediction of its effects but also to using these to the greatest advantage.

Australia is the driest of all the continents and lacks adequate water supplies over wide areas. It is appropriate therefore that Australian scientists in the Division of Radiophysics should be playing a leading part in a series of experiments in cloud physics and artificial rain-making. These experiments have now reached the stage of full-scale field trials to assess whether rainfall can actually be increased significantly over a given target area. The outcome of these trials are of vital interest to the Australian economy.

The Organization is also attacking this problem of water supplies from another angle. In the Division of Industrial Chemistry research is in progress on techniques to retard evaporation of water from dams and other storages. Again in full-scale field trials these investigations have shown that even on large areas of water, losses from evaporation can be very much reduced.

The Organization's major investigations in the field of meteorology are undertaken by the Division of Meteorological Physics at Aspendale, Victoria (*see* Sections 2-7 of this Chapter). The work of the Division of Radiophysics on rain-making is described in Section 8 of this Chapter. The research of the Division of Industrial Chemistry on anti-evaporation of water is described in Chapter XVII., Section 5 (a).

Division of Meteorological Physics.—There have been no major changes during the year in the research programmes being undertaken by the Division.

The Chief of the Division and Mr. W. Swinbank served on the Organizing Committee for the Australia-U.N.E.S.C.O. Symposium in Arid Zone Climatology held in Canberra in October. Several members of the Division attended and contributed to the conference, and the ensuing study tour for overseas delegates and the U.N.E.S.C.O. Advisory Committee terminated at the Division's Headquarters at Aspendale where the major items of research were demonstrated.

Members of the Division have continued to take part in the activities of the World Meteorological Organization which has established working groups in selected subjects to assist in the international aspects of the science of meteorology. The Chief of the Division is Chairman of the group on atmospheric diffusion and a member of that on micrometeorology. He is also a member of the Executive Committee of the International Meteorological Association, which is a division of U.G.G.I.; while Mr. W. Swinbank is a member of the ozone commission of the same body. During the latter part of the year the Chief of the Division has been at the Department of Meteorology in the University of Chicago on an extended visit at the invitation of the Department.

In December, the Chief of the Division and Dr. F. A. Berson attended an international conference on "Tropical Cyclones" organized by the Commonwealth Bureau of Meteorology; and a number of the overseas delegates subsequently spent a short period at Aspendale.

In May the extensive addition to the Division's headquarters building was occupied. This provides new accommodation for various Divisional activities, particularly the instrumental workshops, drawing office, and synoptic laboratory.

2. DYNAMIC METEOROLOGY.

(Division of Meteorological Physics.)

The study of interaction between monsoonal and general circulations in the Australian region previously reported has been temporarily set aside to allow for further intensive field work in the "cool change" project.

(*a*) *Cool Change Project.*—Upper air soundings of temperature, humidity, and wind in rapidly changing weather situations were made at Aspendale serving as a base for the greatly intensified network of recording stations set up in central Victoria for this purpose during the summer. Analysis of the data has served to complement case histories of cool changes from previous seasons. To date the analyses bear out the complexity of the change mechanism, aspects of which have been treated in a semi-climatological survey. It is evident that, in conditions of strong differential heating between land and sea, ensuing circulations of sea-breeze type affect the large-scale air flow and thus usher in the "change" in coastal regions. The process of undercutting by the cold air has been studied in detail.

The flow of cold air from the sea may be influenced by disturbances on the subsidence inversion in the overlying warm northerly air stream. A study of the winter meridional cold front in Western Australia gave evidence for the synoptically significant disturbances of this kind. Their verification in the pressure jump accompanying the summer cool changes of S.E. Australia is one object of current studies.

(*b*) *Wind Surges.*—The problem of surges in slowly changing or sluggish air streams is important, both theoretically and in forecasting practice. The theory of strong katabatic winds previously developed has been tested on the Antarctic coast where the sudden onset and cessation of the violent wind appears to be adequately explained by slow oscillation of the pressure jump line across the coast.

There is some evidence that wind surges in the hinterland of Western and South Australia, especially sharp evening surges at Renmark some 150 miles inland, are intitiated in coastal regions and propagate inland. Though this phenomenon is different from local wind systems such as the katabatic surge in Antarctica, they may well be dynamically similar in origin.

(*c*) *Revolving Storms.*—At the Brisbane conference on "Tropical Cyclones" a paper was presented reporting on a statistical study of the relationship between dominant storm tracks and the trade wind and upper westerlies over Australian waters. There is an indication of a lag relationship which could prove useful in predicting whether a cyclone would pass the Queensland coast or curve southwards and eastwards before affecting the coast.

A preliminary study of storm damage to trees during the passage of a heavy squall-line in the Swan Hill district indicated wind speeds locally exceeding 180 m.p.h.

3. CONVECTION.

(Division of Meteorological Physics.)

Observations of the height of a smoke plume from a heated source have been analysed in relation to wind speed, the results being in good agreement with theory. The generation and maintenance of convection plumes from heated ground has been investigated theoretically, with results confirmed by observation, and a criterion established for assessing the relative importance of free and forced convection as heat transfer agents.

4. MICROMETEOROLOGY.

(Division of Meteorological Physics.)

The principal aim in this work has been, through detailed observation of the fine structure of temperature, water vapour content, and air motion, to study the turbulent mechanisms which achieve the interchange of heat, water vapour, and momentum between atmosphere and Earth.

Following on the experimental finding previously reported that the eddy transfer coefficients for water vapour and momentum are approximately equal, a formula has been developed by which it is possible to evaluate the evaporation from measurements of the vertical gradients of wind speed and humidity. This is an improvement on previous formulations in that it takes proper account of the effects of thermal stratification in a simple manner.

Extensive analysis of observations has confirmed that in conditions of strong convection the pronounced decrease of temperature with height just above the ground changes to zero gradient at an unexpectedly low level, which may be less than 30 feet when the wind is light. This finding is related to observations from experiments designed to elucidate the structure of flow in the air above the ground, which reveal the existence of flow patterns of considerable vertical extent, particularly in conditions of moderate convection.

There is a pressing need in agricultural research as well as in irrigation and water conservation practices for an accurate, automatic method of measuring evaporation from natural surfaces, including vegetative cover and open water storage. Such equipment, based on techniques developed for turbulent transfer studies in the Division, has been developed and is now in field use. The present design requires the attention of a highly skilled operator, but it is planned to simplify it and make it suitable for more general use. This project has involved the development of specialized components, including a linear anemometer and hygrometer and a device capable of integrating a fluctuating current in the microampere range for unrestricted periods.

Since most of the Earth's surface is water, a proper understanding of atmospheric behaviour requires more extensive knowledge of oceanic sources of energy, water vapour, and momentum. There is a reciprocal interest in the atmosphere as a controlling factor in ocean currents and temperatures and so in fisheries problems among others. The programme of micrometeorological observations at sea commenced in 1955 has been continued. F.R.V. *Derwent Hunter* was again lent for a month in November, 1956, by the Division of Fisheries and Oceanography, and a large number of observations secured in Port Phillip Bay and the nearby waters of Bass Strait. In addition to consolidation of results obtained in 1955, new data have been obtained on the eddy fluctuations of wind, temperature, and water vapour. Analysis of these results is still in progress, but the fluxes of heat and momentum so far computed directly from fluctuations are of acceptable magnitude. Values deduced from simultaneous observations of vertical gradients of wind speed and temperature are in moderately close agreement.

5. AGRICULTURAL METEOROLOGY.

(Division of Meteorological Physics.)

A small section has been formed within the Division for the purpose of investigating the meteorological aspects of agricultural problems. Its major interest will be the study of evaporation from soils and growing crops, and for this purpose twelve large soil containers (diameter 5 ft. 3 in., depth 4 ft.) have been installed in the ground on a flat open area to the rear of the Division's buildings at Aspendale. Extensive preliminary work has now been completed, including preparation of the site and construction of a mobile gantry and hoist together with the necessary rail track. As weighing equipment has not yet been developed, the pots will be used initially as potential evapotranspirometers, i.e. they will measure by an approximate method the evaporation from a permanently moistened soil.

The work on frost prevention has finished, and the final comprehensive report on the work over the last six years is nearly completed.

6. OZONE INVESTIGATIONS.

(Division of Meteorological Physics.)

Atmospheric ozone, though small in total amount, and concentrated in the layer 20-50 km above the surface, makes an important contribution to the radiation balance of the atmosphere. Furthermore, measurements made for several years under international auspices in a number of countries, mainly in the northern hemisphere, have revealed a connexion between ozone amount and latitude, season, and synoptic situation. The three Dobson spectrophotometers already adjusted and calibrated in the Division are now in regular use. In preparation for the International Geophysical Year instruments have been placed at Brisbane and Macquarie Island where observations are being made by staff of the Commonwealth Bureau of Meteorology and the Australian National Antarctic Research Expedition respectively. The third instrument will remain at Aspendale, where it has been in use for two years. The data already accumulated are being studied to seek relationships between ozone and the weather situation.

7. MISCELLANEOUS INVESTIGATIONS.

(Division of Meteorological Physics.)

The Division has acted in an advisory capacity for problems relating to primary production and has made special apparatus for a number of Divisions and other institutions. A calibration service for anemometers and air meters is provided for outside bodies.

8. CLOUD AND RAIN PHYSICS.

(Division of Radiophysics.)

The experimental investigations of the physical processes responsible for the formation of cloud and rain which were initiated in the Division in 1947—following the successful demonstration that some clouds could be induced to rain by artificial means—have been actively continued. The original objectives were to provide a sound background against which this potentially important discovery might be assessed, and an indication of whether or not it might be possible to produce economically significant increases in rainfall by artificial means.

While related work has also been proceeding in other countries of the world, it is largely as a result of investigations carried out in Australia that the basic problems involved are now more clearly understood. There are two quite separate processes by which rain occurs in Nature: by ice-crystal formation in supercooled clouds, and by the coagulation or coalescence of water droplets in clouds which are warmer than freezing. The Division's work, described in earlier reports, has established the vital role played in both types of rain by certain minute dust-like particles in the atmosphere known as "nuclei", and that by supplying appropriate substitutes when naturally occurring nuclei are absent or ineffective, rain may be induced artificially. There are indications that supercooled clouds are the more important from the point of view of artificial rain-making. Work has therefore been devoted during the past year, for the most part, to a detailed study of the nature and occurrence of natural "freezing" nuclei (which are responsible for initiating rain from supercooled clouds) and to field experiments designed to show whether useful increases in rainfall may be induced by the use of the most effective artificial freezing nuclei yet discovered, namely, silver iodide.

(*a*) *Cloud Formation and Properties.*—Much information about the formation and development of cumuliform cloud can be gained from a study of the spatial distribution of the liquid water throughout the cloud. This quantity has been measured directly and deduced from the sizes and concentration of the individual liquid droplets. Comparisons of the two methods in the same cloud have agreed in showing a fine structure superimposed on the general cellular pattern of cumulus cloud. In addition, agreement has been obtained on the average magnitude of the liquid water present, which is almost always much less than that predicted from the simple adiabatic model of cumulus development. A theoretical study is in progress in which it is hoped to explain this feature and other characteristics of the spatial distribution of water throughout the cloud.

A study of the observations of the electric charges carried by cloud droplets, combined with information about the natural freezing nucleus concentration in the atmosphere, has been used to develop a theory of electric charge generation and separation in thunderstorms. This theory gives values for the glaciation level and charge distribution that are consistent with commonly observed values.

(*b*) *Natural Rain.*—It is generally recognized that in the temperate regions of the world a proportion of the rain that falls originates in the form of ice crystals in the upper levels of supercooled clouds. These ice crystals in turn are formed upon very small nuclei, the so-called "freezing nuclei", whose nature and distribution have been the subject of study by the Division for the past few years. A remarkable feature of the distribution of these nuclei that has been discovered is the tendency for their concentration to vary simultaneously at widely separated localities.

(i) *Measurements of Freezing Nucleus Concentration.*—Measurements of freezing nucleus concentration have been made using an improved version of the technique described last year. The nuclei are induced to form ice crystals in a supercooled cloud created by the sudden expansion of an enclosed volume of cold saturated air. The crystals are allowed to fall into a shallow dish of supercooled solution where they grow rapidly to dimensions where counting is simple. A number of these pieces of equipment have been constructed for use both in Australia and overseas during the coming year.

During January, 1957, daily observations of freezing nucleus concentration were organized by the Division and made at six widely separated sites in Australia, one at Norfolk Island, and one each on the east and west coasts of the United States of America. A considerable measure of agreement was observed in the day-to-day variation of freezing nucleus concentration at these nine observing stations. During the latter part of the month when all stations were operating there were, in fact, three preferred dates for the concentrations to be higher than average. These dates were close to those predicted on the basis of the meteoritic origin of the nuclei.

(ii) *Meteoritic Dust and Rainfall.*—It has already been reported that examination of world-wide rainfall data shows a strong tendency for rainfall to be greater on certain preferred dates of the calendar year, and that these dates occur approximately 30 days after the Earth's passage through the orbits of various meteor streams. The small particles of meteoritic dust are thought to settle slowly through the atmosphere and act as freezing nuclei when they enter the upper levels of supercooled clouds. Further evidence of these world-wide weather changes has been collected that is consistent with this theory.

Two optical techniques have been developed for detecting the presence of dust in the upper atmosphere. One method reported previously is based on observing changes in the amount of sunlight scattered at various heights and is dependent for success on clear, cloudless weather, both at the observing station and for some hundreds of miles in the direction of observation when measurements are made, which can be done only at sunrise and sunset. Series of measurements were satisfactorily made at Alice Springs during July-August, 1956, and at Carnarvon, Western Australia, from October, 1956, to January, 1957. From these it can be deduced that a layer of dust is always present near the tropopause inversion; there is also a faint indication of a further layer near 80 km. altitude. Owing to their small size, daily variations in " dustiness " are difficult to detect with certainty and the observational data are still being reduced. In the second optical method the light scattered from a searchlight beam is detected and can be used to obtain information on scattering material in the atmosphere at altitudes up to 25 km. This method is less susceptible to interference from distant cloud and should enable more continuous observations to be obtained, when suitably located. A test of this method in January, 1957, showed patches of scattering material, mainly in the 12-15 km. region, which were present on some nights but not on others.

In order to provide current information on meteor activity in the southern hemisphere, the regular observations by radio methods, already begun at the University of Adelaide, have been continued.

(iii) *Cirrus Cloud and Rainfall.*—The incidence of cirrus cloud at representative stations throughout Australia during the month of January, taken over the longest period for which reliable observations are available (1939-1956), has been found to show variations of large amplitude which correspond very closely to those of the rainfall for a much longer period and wider area. The occurrence of cirrus cloud indicates the presence of freezing nuclei in the upper atmosphere, and its greater abundance some 30 days after meteor showers provides further support for the theory that meteoritic dust gives rise to nuclei which may subsequently affect rainfall.

(*c*) *Artificial Rain Formation.*—Experiments in artificial rain formation have followed three patterns: attempts to stimulate rain over large areas; seeding of individual clouds; and more detailed investigations into the processes involved.

(i) *Large-area Seeding.*—The large-area seeding experiments have followed the lines shown to be desirable by the previous work of the Division, silver iodide smoke being released into clouds from aircraft.

(1) *The Snowy Mountains project*: The Snowy Mountains project is being continued in co-operation with the Snowy Mountains Hydro-electric Authority and has now been in operation for two winter seasons. It is suspended during the summer months. Clouds over a target area have been seeded with silver iodide smoke released from the Division's Anson aircraft, supplemented in the later stages by a DC-3 of the Royal Australian Air Force. A Hudson aircraft, chartered by the Authority, is to be used in future. The rainfall in this target area is compared with that in an adjacent unseeded area. The seeding season is divided into periods of approximately two weeks' duration; during the whole of any one period clouds over the target area may or may not be seeded, the choice of whether to seed being on a random basis. The relation between the natural rainfall in the target and control areas is determined during the unseeded periods. In the seeded periods, there has, on the whole, been an increase in the rainfall in the target area. The difference between the seeded and unseeded periods is about the 95 per cent. level of significance, and the most probable magnitude of the increase in rainfall is 15 per cent. In those periods when most seeding has taken place the increase has been greater.

Operations will be continued for at least another year to enable the results to be more reliably defined.

(2) *South Australian experiment*: An experiment similar to that over the Snowy Mountains has been begun in South Australia. Two areas, each of approximately 1,000 square miles, have been selected in the Mount Lofty Ranges north of Adelaide. Clouds over one or other of these areas are seeded with silver iodide smoke released from an aircraft, for a period of about two weeks; the choice of which area is to be seeded is made on an entirely random basis. This principle is expected to increase the ease of detection of the results compared with that used in the Snowy Mountains trials, where only one area is seeded.

The experiment commenced in April, 1957. It will be restricted to the winter months only, and will continue until significant results are obtained, which might take about three years.

(3) *The Kiewa project*: In this experiment silver iodide smoke was released from a generator on Mount Stanley, Victoria, in order to seed clouds over the Kiewa Catchment Area, in co-operation with the State Electricity Commission of Victoria. Two years' operation gave no detectable results. Flight trials revealed that the output of the generator was insufficient. Attempts to increase the output met with difficulties and the experiment has therefore been abandoned. A final report is in course of preparation.

(4) *Drought emergency operations*: Special emergency operations were commenced towards the end of June, 1957, in an attempt to induce the maximum possible precipitation from any suitable cloud formations that might occur over general areas of the eastern States where drought conditions were beginning to be experienced. Two Dakota aircraft have been made available by the Royal Australian Air Force and equipped for airborne seeding with silver iodide, and these, together with other aircraft already being used by the Division for experimental investigations, have been based at strategic points in Queensland, New South Wales, Victoria, and South Australia, in readiness to seed any suitable cloud that may appear. The Departments of Agriculture in each State are co-operating, and nominating specific areas in their respective States where the need for rain is most urgent.

(ii) *Stimulation of Individual Clouds.*—(1) *Silver iodide*: Silver iodide smoke has been introduced into individual clouds by flying through them with an aircraft equipped with a smoke generator. This has been done, and the results have been observed on many occasions during the last few years. The results of all these experiments have been collected, and a report has been issued.

(2) *Electrical techniques*: Attempts are being made to increase the coalescence rate of cloud droplets by charging them to opposite polarities. Apparatus has been constructed and installed in a Lincoln aircraft of the Royal Australian Air Force. A petrol-electric generator supplies current to a high-voltage transformer, from which it is fed to long wires extended below the aircraft by a trailing " bomb ". This " bomb " has been flight tested, and the complete installation will shortly be ready for operational trials.

(iii) *Properties of Silver Iodide.*—(1) *Aircraft generator*: A generator of silver iodide smoke on the wing of an aircraft, of the type used in the large-scale seeding experiments, has been tested by flying through the smoke thus produced in another aircraft equipped to measure the output of freezing nuclei. The burner was found to produce large numbers of nuclei of acceptable properties.

(2) *Preparation of nuclei*: A start has been made on alternative methods of production of silver iodide nuclei. The objectives are nuclei of longer life, and increased numbers of nuclei per gram of silver iodide.

XXVIII. EXTRATERRESTRIAL PHYSICS.

1. GENERAL.

The discovery that radio waves as well as light can be used for studying the heavenly bodies has provided a new research technique for exploring the universe. Working side by side with scientists using optical methods, radio astronomers have been able to uncover new knowledge, not only of the Sun and planets from our solar system, but also of the galaxy of which we are part and the innumerable galaxies beyond. The radio telescope has set new boundaries to space, far beyond those at the limit of optical vision. Nor is this all that radio astronomy has done. Study of the 21-centimetre spectral line of atomic hydrogen has yielded a new conception of the distribution and the nature of the matter pervading interstellar space and the transformations which this matter undergoes in the creation of the heavenly bodies.

Radio astronomy has formed a major part of the research programme of the Division of Radiophysics (*see* Section 3 of this Chapter). Studies of the ionosphere are carried out by the Radio Research Laboratories (*see* Chapter XXVI., Section 7). Work on solar radiation is carried out by the Division of Physics (*see* Section 2 of this Chapter) and cosmic ray investigations at the University of Tasmania (*see* Section 4 of this Chapter).

2. SOLAR PHYSICS.

(Division of Physics.)

The field of solar physics abounds with major unsolved problems. These include—

(*a*) the nature of the physical conditions in the outer layers of the Sun (the photosphere, chromosphere, and corona) and their temporal and spatial variations;

(*b*) the nature and origin of the various solar disturbances, such as sunspots, plages, flares, prominences, and enhanced radio-frequency and particle emission;

(*c*) the nature of solar magnetic fields and their influence on various aspects of solar activity; and

(*d*) the heat balance throughout the Sun's atmosphere.

Most of these problems are susceptible to direct observational attack, though this may need to be undertaken with the aid of novel techniques.

New methods and equipment have been and are being developed in the Division for a study of a number of these problems. The most important item is to be a tunable 1/8 Å birefringent filter, centred on the hydrogent line H_α. This filter, whose completion is anticipated in 1957, will have a spectral resolution of about 50,000, which approaches that obtainable with high-quality spectrographs; but in addition, it will have a large field of view. Observations with it will provide valuable information on the physical conditions throughout the Sun's chromosphere.

The filter is to be mounted on a 10-ft. equatorial spar which has been erected at the Fleurs field station, some 30 miles west of Sydney. The spar carries a 5″ photoheliograph equipped with vacuum suction devices near all irradiated surfaces to prevent optically undesirable convection currents and so reduce atmospheric scintillation. It is at present being used for cinematographic studies of photospheric granulation and of sunspot growth.

The horizontal telescope at Sydney, which is used with a Lyot H_α monochromatic filter for cinematographic observations of the chromosphere over the full disk of the Sun, is also being equipped for the cinematography of flare and prominence spectra. Chromosphere observations with this instrument have been made continuously, weather permitting, for the past 18 months. Correlations of these data with radio-frequency observations obtained by the Division of Radiophysics have shown that there is a close connexion between type III radio-frequency burst and flares, or microflares, the cause of which is still being sought.

Considerable attention is being devoted to a study of flare types. There is now clear evidence that some flares move at high velocities, in rare cases up to 300 km./sec., and that others eject diffuse bright clouds of hydrogen atoms which eventually darken to appear, when on the disk, as the well-known dark hydrogen surges.

Observations with these two pieces of equipment will be continued and intensified as part of Australia's contribution to the International Geophysical Year 1957-58. Because of the scarcity of solar observatories in these longitudes, observations in Australia are vital to the continuity of solar watching, which forms a major part of the overall plan for the International Geophysical Year. Staff has been trained for these purposes and the scheme is already in operation.

3. RADIO ASTRONOMY.

(Division of Radiophysics.)

Access to the vast store of latent astronomical knowledge conveyed by the radio signals which are constantly reaching us from outside the Earth depends on overcoming the very difficult technical problems involved in producing radio telescopes of high angular resolution. The Division's contribution to this problem has been the development and construction of four unique instruments, each more powerful in accomplishing the purpose for which it is designed than any which exist elsewhere in the world. The Australian techniques, however, are now being adopted abroad, particularly in the United States of America.

Last year saw the completion of two large "Mills Cross" aerials for the study of radio waves from beyond the solar system. While results from these and other instruments are being accumulated and analysed, this year's constructional programme has been focused on instruments for observing the Sun. The largest instrumental undertaking has been the erection of a crossed-grating interferometer, consisting of 64 separate parabolic aerials each of 19-ft. diameter and capable of following the Sun. This will provide, at frequent intervals throughout each day, high-resolution radio "pictures" of the Sun, at a wavelength of 21 cm. The second instrument is a rapid scanning ("swept-frequency") interferometer for recording the instantaneous position, motion, size, and spectrum of the short-lived burst of high-intensity radio waves which appear spasmodically on the Sun's disk at wavelengths of a few metres. Both instruments are now in operation, ready for the start of the special series of observations to be made during the International Geophysical Year.

The Division is anxiously awaiting the results of the design study being carried out by the British engineers, Messrs. Freeman, Fox, and Partners, for the proposed giant radio telescope. This instrument will be essential if Australia's unique international position in the field of radio astronomy is to be maintained.

(*a*) *Radio Waves from beyond the Solar System.* (i) *The Spiral Structure of our Galaxy.*—A long programme of observations of the southern part of the Milky Way at a wavelength of 21 cm. has yielded interesting results relating to the general structure of our Galaxy. This work has been done with the Division's 36-ft. paraboloid. At this wavelength, radiation is received from interstellar hydrogen over a narrow wavelength band.

Although the density of this hydrogen is very low, its total mass is considerable, and it can be used to delineate the shape and structure of the whole Milky Way Galaxy.

The southern observations, together with those from the northern hemisphere obtained at Leiden, give for the first time an overall picture of the spiral structure of almost the whole of the Galaxy, far beyond the region which can be studied optically. The pattern shows a number of long spiral arms sweeping around the Galaxy, trailing slightly behind the direction of ratation.

The hydrogen is found to be concentrated into a very thin layer. The disk of hydrogen is only 800 light-years thick, although its diameter is about 80,000 light-years. In the parts of the Galaxy closer to the centre than the Sun, the hydrogen layer is very flat, but the new observations have shown that the layer is systematically distorted in the outer regions of the Galaxy. The layer is bent downwards on the side of the Galaxy nearest to the Magellanic Clouds, and upwards on the far side. These clouds, which are really satellite galaxies, are apparently affecting the shape of our Galaxy. The observed effect is larger than would be expected gravitationally, and some other type of force may be acting.

When these observations have been completely analysed, they will lead to a three-dimensional model of the distribution and motion of the interstellar hydrogen throughout the Galaxy.

(ii) *Results from the* 3.5-*metre "Mills Cross" Aerial.*—During the year the survey of the southern sky with the 3.5-metre cross aerial has been completed and the results are now being analysed. Several thousand discrete radio sources, or "radio stars", are visible on the records, and one of the major activities at present is their cataloguing. A preliminary catalogue has already been published containing 383 radio sources in a limited area. About a dozen of these may be identified with relatively bright nebulae, but it is apparent that the great majority are unidentifiable. This is to be expected since it has long been known that outstanding radio objects are very faint optical objects; the conclusion follows that the majority of the radio sources are at very great distances. A comparison of this catalogue with a recent catalogue prepared at the Cavendish Laboratory, Cambridge, reveals very marked discrepancies. The latter lists 227 sources in the sample area, but only about 60 sources agree within the limits of error with those derived here, and, of these, about 40 chance coincidences might be expected. An analysis of the performance of both instruments suggests that the Cambridge survey is seriously affected by inadequate resolution. Similarly, some conclusions about the nature of the universe derived from a statistical analysis of the Cambridge survey are not supported by the Division's results.

In addition to the cataloguing of radio sources, maps are being prepared of the distribution of radio emission along the Milky Way. The distribution is surprisingly complex, and it seems clear that a detailed analysis will yield useful information about the composition of the Galaxy. Features relating to the large-scale structure of the Galaxy are clearly evident.

Several radio sources have been occulted by the Moon in the last year and preparations were made for observing all these. In one, the nebula IC443, it was possible to combine the occultation observation with direct observations using the cross to prepare a model of the radio source. This was found to be closely similar to the optical appearance of the nebula, an unusual circumstance. Other observations were not so successful, principally because of radio interference, but it was possible to confirm an identification between a radio source and the remnants of a supernova observed by Kepler in 1604.

During the year it had been planned to add a facility to the cross to permit measurement of the angular size of very small sources which are probably very distant extragalactic nebulae. This would enable many more identifications with optical objects to be made and would also quite likely yield information about some basic questions in cosmology. However, the plans had to be shelved because of lack of funds.

(iii) *Observations with the* 15-*metre Wavelength Cross Aerial.*—This equipment was first put into operation in May, 1956, and has since been used in the study of cosmic radio noise. The aerial consists of two arrays of half-wavelength dipoles, each array being about 3,500 feet in length, erected alongside the 3.5-m. Mills Cross. The general design is broadly similar to that of the 3.5-m. aerial, although the longer wavelength has permitted less critical tolerances in construction. For example, no special reflector is used, the dipoles of the arrays being all at the same height above the ground; small ground irregularities are insignificant at 15 m. Provision is made for directing the aerial, electrically, to different declinations in coarse steps by switches which must be changed by hand, together with finer steps controlled by relays which automatically switch the aerial in succession to one of five closely spaced declinations.

The receiving equipment again follows the general scheme of the 3.5-m. equipment, but special provision had to be made to overcome a problem peculiar to observations at wavelengths of the order of 15 m., namely, that of avoiding interfering signals from commercial telecommunications transmitters. In this equipment the bandwidth has been kept down to 4 Kc/s, and the frequency can be set anywhere in a limited band so that the actual operating frequency is set in a clear channel between interfering stations. In actual practice there are four separate receiving channels which can be adjusted independently in frequency so that, under favorable conditions, four times the minimum bandwidth can be used, giving twice the sensitivity. Normally there is an observer in attendance so that the records can be continually monitored.

The importance of observations at wavelengths of about 15 m. lies in the possibility of detecting the absorbing effects of the region of ionized hydrogen (the so-called HII regions) scattered throughout the Galaxy. These HII regions are sometimes seen optically as glowing clouds of gas, and they are also observed in emission at short radio wavelengths. However, at low frequencies, they act as absorbers of the bright background (non-thermal) radiation, and since they are concentrated near the galactic plane the brightness temperatures observed near the galactic equator should not rise, relatively, as high as they do at shorter wavelengths. In fact, the high resolution of the present equipment has revealed that the HII absorption is so high at 15 m. that a "dark" band is seen along a large part of the galactic equator. A detailed study should give important information concerning both the distribution of the sources of galactic radio emission and also the spiral structure of the Galaxy.

An interesting observation is that the giant HII region 30 Doradus in the Large Magellanic Cloud has been observed in absorption. This leads to the possibility of determining the relative importance of galactic and extragalactic sources of the radio emission observed at high galactic latitudes.

(*b*) *Radio Waves from the Sun.* (i) *The Crossed-grating Interferometer.*—A new crossed-grating interferometer, designed for high-resolution observations of the Sun, was completed during the year and is now in operation. This instrument consists of a cross-shaped array of 64 parabolic aerials, each 19 feet in diameter and designed to follow the Sun in its movement over the sky. The instrument, which produces pencil beams of width less than one-twentieth degree, will be used to produce daily maps of the solar disk on which the position and brightness of the regions of high radio emission will be displayed. By this means, it will be possible to follow the development of these active regions and, it is hoped, gain some knowledge as to their nature.

An earlier investigation, made during the minimum sunspot period of the solar cycle, has given very useful information about the position of these regions in the solar atmosphere, their shape, rate of decay, and relation to optical features of the solar disk.

The regions are of practical interest, since they appear to be responsible for changes which occur in the Earth's ionosphere, and these changes, in turn, affect short-wave radio communications.

(ii) *The Swept-frequency Interferometer.*—In conjunction with the Division's solar radio spectroscope, which has been in operation since 1952, a "swept-frequency" interferometer has been constructed for the purpose of determining the position, motion, and size of the remarkable high-intensity bursts of radiation which are emitted sporadically from the Sun at wavelengths of between about 1 and 10 m.

Positional accuracy of about 1 min of arc is required, and this is being obtained with a two-aerial system extending over a baseline of 1 km.

The instrument has been designed to solve current problems relating to the origin of these bursts; this necessitates positional information over a wide range of wavelengths. A problem of special interest is the examination of a hypothesis advanced as a result of our past spectroscopic observations that certain bursts ("spectral type IV.") trace the outward passage through the Sun's atmosphere of corpuscular streams at speeds approaching the speed of light.

Other techniques employed during the year in conjunction with the solar spectroscope have yielded polarization observations over a continuous band of frequencies and established the polarization characteristics of different spectral types of bursts. An investigation conducted in conjunction with optical observers of the Division of Physics has established a marked correlation between the radio "type III." bursts and optical flares.

(iii) *The International Geophysical Year.*—The Division is making a substantial contribution to the fund of data for the International Geophysical Year which begins in July, 1957. In addition to the supplying of unique data from the two solar instruments described above and from the routine solar recording instruments, the editing of world data on solar radio emission will be undertaken by an officer of the Division.

(*c*) *Radio Waves from Jupiter.*—At the time of the last Annual Report, a series of observations of radio radiation from the planet Jupiter had just concluded. These observations have now been analysed and a paper submitted for publication.

Besides generally confirming the results of earlier work and of work in the United States of America, these observations have given new information on the spectrum and temporal characteristics of the Jupiter noise. The spectrum shows a marked maximum of intensity at about 20 Mc/s and suggests that the radiation originates in some ionized region on Jupiter having a plasma frequency of about 20 Mc/s. However, it is difficult to explain an observed cone of emission narrower at 27 Mc/s than at 20 Mc/s.

The most important observation on the time structure of the bursts was that when observations were made simultaneously and at the same frequency at two sites separated by 25 km., there was general similarity, but little detailed correlation between the two records. This suggests a new type of ionospheric scintillation associated with the small angular size of the source on Jupiter.

(*d*) *Theoretical Studies in Cosmical Electromagnetics.*—Theoretical studies concerning radio astronomy have gradually extended in scope to include many electromagnetic aspects of cosmical physics.

On the purely theoretical side the basic problem is an understanding of all forms of waves in a magneto-ionic medium. Earlier studies of weak waves have been extended to strong hydromagnetic waves. The very powerful damping effect of neutral atoms has been studied further, and it is found that hydromagnetic waves may transfer some of their energy directly to excitation and ionization without the intermediate step of heating the gas. Studies of theories of growing electric space-charge and radio waves have been extended and completed.

These purely theoretical results have been applied to several astrophysical problems. The neutral-atom heating and ionizing effects very likely provide a partial explanation of solar flares, plages, and other chromospheric phenomena. The same effect is likely to be important in connexion with galactic turbulence and so in theories of the origin of cosmic rays. A detailed study of the electromagnetics of the Crab nebula has been made, with the conclusion that magnetic field is being created there on a vast scale.

A mechanism which may explain the operation of the "electron wave" amplifier and similar devices has been found. Its very simplicity suggests widespread occurrence in nature—the solar atmosphere, interstellar space, and, perhaps, the ionosphere.

4. Cosmic Ray Research.

(University of Tasmania.)

In the investigation of the long-term changes in the east-west asymmetry of the hard component of cosmic rays, records from Hobart have shown that the asymmetry gradually decreased during the years following 1948 until a minimum was reached in 1955. Since 1955 it has increased, and the evidence suggests a correlation with the cycle of solar activity. These results, together with a discussion of their implications, have been published in a recent paper.

An investigation of the observed diurnal variation of the barometer coefficient for the hard component has resulted in the publication of a paper discussing its possible origin either in purely meteorological effects or in variations of the energy spectrum of primary cosmic rays.

The development of short-term recording techniques has also been carried out, and an examination of records from an automatic printing register is now being made. These techniques allow detailed examination of the form of short-term intensity fluctuations such as magnetic storm and solar flare effects.

Investigations are also proceeding on comparison of neutron intensities at sea-level and 2,400 feet, and comparison is being made of hard-component cosmic ray intensities under 10 cm. of lead, 20 cm. of lead, and 50 feet of earth.

XXIX. MATHEMATICAL STATISTICS AND MATHEMATICS.

1. General.

Mathematical work plays an important part in all phases of the Organization's research programmes. A separate Division of Mathematical Statistics is maintained to provide workers in the various Divisions and Sections with specialized help in planning their researches and analysing their experimental results (*see* Section 2 of this Chapter).

Work on mathematical instruments and mechanical and electrical methods of computation is undertaken in the Section of Mathematical Instruments (*see* Section 3 of this Chapter).

Division of Mathematical Statistics.—The pattern of the Division has undergone little material change during the past 12 months. The staff of the Division is now established at 11 centres throughout the Organization, and close liaison is maintained both with and between these officers and also with the staff of the various Divisions in which they are established. By means of this close association statistical help is available to research staff throughout the

Organization from the initial stage of the design of experiments throughout the course of the research projects concerned.

This advisory work is not described here as the various projects have been discussed in detail in other chapters. However, along with this work a number of investigations are undertaken within the Division's own research programme, and a brief account of the nature of these is given below.

Requests for assistance from individuals and establishments, both Government and otherwise, have continued to be demanding, and courses of lectures have been provided within the various universities with which the Division is associated.

Dr. E. J. Williams has been granted leave, in order to accept an appointment as visiting professor in the Department of Experimental Statistics of the North Carolina University, Raleigh, United States of America.

Some members of the Division's staff have taken an active part in the recent formation of the Australian Mathematical Society; and an officer contributed to the conference on Data Processing and Automatic Computing Machines at the Weapons Research Establishment, Salisbury.

Grateful acknowledgment is made to the Weapons Research Establishment in allowing the Division access to its computor "WREDAC" in connexion with analysis of rainfall correlations; and also to the University of Melbourne for accommodating a Divisional Officer within its Computation Laboratory.

Mathematical Instruments Section.—As in past years the Section has worked in close co-operation with the Electrical Engineering Department of the University of Sydney. There have been no major changes in the research programmes of the Section. Grateful acknowledgment is made of donations from Dr. A. Basser of the University of Sydney and the Snowy Mountains Hydro-electric Authority.

2. MATHEMATICAL STATISTICS.

(Division of Mathematical Statistics.)

The following is a summary of research projects completed or in progress within the research programme of the Division of Mathematical Statistics during the current year:—

Investigations have been made of applications of the theory of group representations and the use of associative algebras in the design and analysis of experiments. Analysis of variance and covariance of incomplete experimental data have been studied. Computation has been undertaken of the coefficients in the expansion of the general distribution of canonical correlation coefficients using a generating function for averages over the orthogonal group.

Research has been continued on interpolation of monthly rainfall in terms of the position and altitude of observing stations, as a result of which the accuracy of interpolates can be increased considerably.

Investigation of intercorrelations of monthly rainfall has been completed, and the major role of frontal rains in establishing the spatial distribution of rainfall correlations in south-eastern South Australia demonstrated. This work provides a very large amount of quantitative information on the degree of association of rainfall over large distances (up to 450 miles) and for any direction of displacement from a given point.

Applications of statistical theory in production engineering processes and in engineering design analysis have been investigated.

In collaboration with the Mathematics Department of the University of New England, the distribution of the rank correlation coefficient has been derived when the sample numbers are small and numerous ties exist among the rankings.

3. MATHEMATICAL INSTRUMENTS.

(Mathematical Instruments Section.)

Construction of A.D.A., a transistor decimal digital differential analyser, which was commenced in 1956, is now reaching its final stages, and full-scale testing will commence shortly. A second machine of a similar but more advanced type is being planned for the Snowy Mountains Hydro-electric Authority.

Meanwhile the major task for the mechanical differential analyser has been the investigation of non-linear control systems by the Division of Radiophysics.

XXX. RESEARCH SERVICES.

1. LIBRARIES.

The Organization's library system has continued to concentrate upon the co-ordination of its services as referred to in the last report. This has been facilitated to a considerable degree by a marked improvement in recruitment in the past year. The appointment of highly qualified senior staff in the various libraries will enable the librarians to extend more rationally their prime function of developing and providing bibliographic services.

Plans have been finalized for editing and publishing a loose-leaf union catalogue, "Scientific Serials in Australian Libraries", which will supersede the "Union Catalogue of Scientific and Technical Periodicals in the Libraries of Australia". This will, it is hoped, provide research workers and librarians with an up-to-date finding list.

Another successful meeting of librarians was held at Head Office in May, 1957. Included amongst the important resolutions carried at this meeting was the decision to compile, for use in the libraries, a subject index to the List of Publications. The appropriate librarian in each of the fields covered by the Organization will be responsible for the indexing of the material issued by the Divisions or Sections.

The Abstracts of Papers and List of Translations was expanded to include an alphabetical subject index to a restricted coverage of Australian periodicals. This has proved useful, and a committee of senior librarians is now assisting with its editing and in securing as wide a coverage as possible.

The card index to the work of the Organization's research staff has made much progress in the past year. Although the collection of material is still far from complete, a lot of gaps have been filled and for bibliographic purposes the collection is now much more reliable.

Use of the Organization's libraries continues to increase. This is shown by a comparison of requests for specific references, subject bibliographies, and general subject inquiries channelled through Head Office which have risen from 4,565 in the first six months of 1954 to 13,236 in the same period in 1957.

2. TRANSLATION.

The Translation Section has performed its usual translation work, written and oral, for Divisions and Sections. Some help by way of oral translation has been given to research workers in outside bodies.

The Section has operated as Australian agent for the Index of Translations of the British Commonwealth Scientific Office.

Microfilm copies of all the Section's translations from Russian have been sent to the John Crerar Library, Chicago, the approved body in this respect in the United States of America.

The languages that can be handled by the Section are: German, Dutch, Swedish, Norwegian, Danish, French, Italian, Spanish, Portuguese, Russian, Polish, Ukrainian, and Lettish. For other languages use is made of outside translators.

3. Engineering Section.

The Engineering Section provides assistance and advice to the Divisions and Sections of the Organization in the engineering problems which they encounter from time to time. Although these problems cover a wide and varied range, the main emphasis is on work associated with the control of temperature and humidity in enclosed spaces; a correspondingly large proportion of the Section's activities is therefore devoted to the study of environment control, and to the development of equipment and systems for specialized research applications.

Another major interest is in the study of solar radiation, both from its influence on problems such as the cooling of glass-houses and from the aspect of the useful employment of solar energy. The Section also undertakes the design and manufacture of special-purpose or pilot-scale machines and equipment to the requirements of Divisions, and assists those in Melbourne on installation and maintenance tasks.

(*a*) *Solar Energy*.—Recently at the National Physical Laboratory of Israel it was shown that certain surfaces had the ability to absorb selectively heat energy of differing wavelengths. Specifically it was found possible to produce a surface which had a high absorbtivity for solar radiation and a low emissivity for the long wavelength re-radiation from an absorber operating at about 300° F. This is of special significance in connexion with the utilization of solar energy by thermal processes. Accordingly the properties of these surfaces are being studied, together with satisfactory means for producing them.

Considerable interest has been shown in the work which resulted in the development of a practical solar water heater for domestic use. During the year an improved type of absorber was announced consisting of an asbestos cement base covered with two glass sheets supported only at the edges. This unit is approximately 4 feet square and 5 inches deep and is very suitable for quantity production. It is now being manufactured commercially in New South Wales, Victoria, and Western Australia.

(*b*) *Phytotron Project*.—Some progress was made during the year on the design and development of a phytotron for the study of plant growth under controlled conditions. This term originated at the Earhart Plant Research Laboratory, California, and was used by Dr. F. W. Went to describe his laboratory facilities for controlling day-time temperature, night-time temperature, and day length under conditions of both natural and artificial lighting. He has shown that, when plants are grown under such controlled conditions, not only are completely new fields of investigation opened up, but results can frequently be achieved in much shorter time than would be possible any other way. Accordingly his techniques are being followed in a number of countries outside the United States. In view of its value to Australian biological research the Engineering Section has undertaken the design and development of a novel type of phytotron consisting of a large number of cabinets in each of which the day temperature, night temperature, and length of day can be separately controlled. These cabinets are located in a glass-house and the plants grown under ordinary natural daylight conditions. Provision is also made in the phytotron building for the growing of plants under artificial illumination.

Three prototype cabinets have been operating since January, 1957, and the outline design for the final project has been completed.

(*c*) *Air-conditioning*.—In addition to the specialized forms of air-conditioning involved in the control of environment for research on plants and animals, a continuing requirement exists within the Organization for more conventional systems for standards rooms and similar applications. The unit conditioner developed by the Section is now in use in many Laboratories, and in its latest form the earlier three-phase electrode-boiler type of humidifier has been replaced by a single-phase unit to give improved performance and reduced maintenance.

During the year several laboratory air-conditioning installations were carried out, one of the more interesting being that at the Wool Textile Research Laboratory, Geelong. The requirement in this case was for control of relative humidity in a large area used for textile processing, and it was found possible to meet this satisfactorily by the use of ten separate conditioners; by this means the cost and complexity of the installation was reduced considerably below that of a conventional system using ducted air from a large central plant.

(*d*) *The Heat Pump*.—The Section is studying the " heat pump " principle with a view to its employment in both the space heating and space cooling of buildings. An experimental installation, drawing its heat from the outside air, is being constructed in order to obtain operating data during the Melbourne winter.

(*e*) *General Engineering*.—During the year several interesting machines and items of equipment were constructed and put into operation. These included a large experimental cheese cheddaring machine, developed in conjunction with the Dairy Research Section and built mainly in stainless steel (*see* Chapter XIII., Section 12). This machine has proved very successful in operation, and designs are at present being prepared for a salting and hooping machine for use in conjunction with it. A pad mangle has been designed and built for the Wool Textile Research Laboratories, Geelong, for the removal of surplus shrinkproofing solution from lengths of fabric. The mangle has 33-in. rollers which can be driven at varying speeds and can be loaded hydraulically up to a total pressure of four tons. A similar machine, but with 66-in. rollers, is now being built for the same purpose.

In recent years there has been considerable interest in the use of the lysimeter for evapotranspiration studies. The equipment consists essentially of a large soil container, buried with its surface flush with the ground, and mounted on a highly sensitive weighing device. The value of the results obtained depend to a large extent on the accuracy with which very small changes in the weight of a large soil mass can be detected and recorded. A successful design has been recently developed by the National Institute of Agricultural Engineering in England, and the Section is at present manufacturing two units to this design for use at the Merbein and Griffith Research Stations.

(*f*) *Engineering Research Review*.—The Section has now produced the first issue of the " Engineering Section Review ", designed to provide Members of the Organization with brief illustrated descriptions of equipment of general interest for which designs are available. Further issues will be produced from time to time.

XXXI. PUBLICATIONS, EXTENSION AND LIAISON ACTIVITIES.

1. General.

The Organization's research results are made available through various channels.

Formal scientific publication is supplemented in several ways: by the preparation of films (Section 6 of this Chapter) which may, for example, give a farmer or extension officer more help in diagnosis of animal diseases than would a list of clinical data; by the continuous and close contact with industry of officers of the Divisions and Sections, through whom much information—derived from the literature, accumulated knowledge and experience, and current research—is disseminated; by the provision of facilities for guest workers in laboratories; by the publication of trade circulars, newsletters, and articles for trade journals; by press releases; by lectures and short courses of specialized training; and by the organization of specialist conferences.

The application of research in the primary industries is being assisted by the work of the Agricultural Research Liaison Section (Section 3 of this Chapter).

The application of research in the secondary industries is being assisted by the newly formed Industrial Research Liaison Section (Section 4 of this Chapter).

Section 5 of this chapter deals with the work of the Organization's Scientific Liaison Offices in London and Washington.

2. PUBLICATIONS.

During the year the Executive concluded an agreement with the Council of the Australian Academy of Science on co-operation between the two bodies to ensure the maintenance of a high standard in papers appearing in the following scientific research journals published by the Organization:

- *Australian Journal of Agricultural Research.* Six issues a year.
- *Australian Journal of Applied Science.* Issued quarterly.
- *Australian Journal of Biological Sciences.* Issued quarterly.
- *Australian Journal of Botany.* Issued as material becomes available.
- *Australian Journal of Chemistry.* Issued quarterly.
- *Australian Journal of Marine and Freshwater Research.* Issued as material becomes available.
- *Australian Journal of Physics.* Issued quarterly.
- *Australian Journal of Zoology.* Issued as material becomes available.

General editorial policy is decided by a Board of Standards comprising Professor J. G. Wood (Chairman), Dr. N. S. Noble (Editor), Professor J. S. Anderson, Professor Sir Macfarlane Burnet, Professor L. H. Martin, and Professor W. P. Rogers. Advisory Committees are responsible for editorial matters affecting each individual journal, and members of the Board serve on appropriate journal committees.

The Royal Australian Chemical Institute collaborates in the publication of the *Australian Journal of Chemistry*, the Institute of Physics (Australian Branch) collaborates in the publication of the *Australian Journal of Physics*, and the Australian Veterinary Association and the Australian Institute of Agricultural Science collaborate in the publication of the *Australian Journal of Agricultural Research.*

The journals listed above are open to receive contributions of merit from research workers, irrespective of country or of the establishment to which they are attached. Many papers from workers in Australian universities and a limited number from overseas have been published, and the steady increase in the annual volume of the journals represents growing support from all sources.

The Organization's research results are published in the above-mentioned journals, in its Bulletins and the Technical Papers of its Divisions and Sections, and in special series such as the " Land Research " series and the " Soil Publication " series. Many research papers are also contributed by officers of the Organization to specialized scientific journals both in Australia and overseas.

A complete list of scientific papers published during the year by officers of the Organization will be found in Chapter XXXIV.

New publications issued by the Organization during the year include:

(*a*) *C.S.I.R.O. Industrial Research News*: An illustrated publication appearing initially at intervals of two months, to bring information on the Organization's current research developments to the notice of firms engaged in secondary industry.

(*b*) *Coal Research in C.S.I.R.O.*: A new periodical giving a commentary on the investigations in progress at the Coal Research Section, which will form a link between the Section and those who are interested in the production and utilization of coal.

(*c*) *C.S.I.R.O. Wildlife Research*: A medium for the publication of the results of the research of the Wildlife Survey Section, mainly on mammal and bird ecology, control, and conservation. It is intended to publish one volume per annum, comprising two numbers.

3. AGRICULTURAL RESEARCH LIAISON SECTION.

The broad objectives of agricultural research liaison are to reduce the lag between the time when research results are obtained and their impact on agricultural production, and to keep research staff informed regarding agricultural situations in which research could lead to increased or more efficient production.

The Agricultural Research Liaison Section is doing this in several ways. Firstly, by means of semi-technical publications such as the periodical *Rural Research in C.S.I.R.O.* and a series of Leaflets, it is presenting complex scientific findings in a more readily assimilable form, and in broader agricultural perspective. This work has continued during the year, but lack of adequately trained staff has restricted activity in this field.

Secondly, the Section is endeavouring to achieve a similar end by personal liaison. A major move during the year in this field of activity has been the development of a new liaison technique based on co-operative studies on a broad regional basis. The Section is co-operating with the New South Wales Department of Agriculture in an assessment of the existing and potential agricultural resources of the Southern Tablelands region. The research establishments of the Organization are providing detailed information regarding the soils, vegetation, climate, and other physical features of the environment, while the Department of Agriculture in assessing the use to which these resources are being put by farmers at the present time.

This regional project, which is now at the fact-finding stage, is scheduled for completion by the end of 1958. A cooperative planning committee will, in the final stages, outline the factors at present limiting production, and make recommendations to the appropriate bodies concerning further extension, and, if indicated, list additional problems requiring solution through research.

Direct liaison on a subject matter basis has also continued during the year. Participation by officers of the Section in a number of specialist conferences and attendance at meetings sponsored by State Departments of Agriculture has facilitated this important phase of liaison.

4. INDUSTRIAL RESEARCH LIAISON SECTION.

This small section has a responsibility for providing a liaison service in fields that are of common interest to the Organization and to industry. The Section has collaborated with the Australian Institute of Management in arranging discussion groups on aspects of industrial research. It has provided assistance to industrial firms and associations of firms in the establishment or expansion of their research activities. It has served as a channel whereby companies have arranged for sponsored projects to be undertaken in the Organization's laboratories.

A major objective of the Section is to assist in transferring to operating practice in industry the results of research carried out in the establishments of the Organization. To assist in bringing information on current research developments to the notice of industrial firms, a new periodical, *C.S.I.R.O. Industrial Research News,* has been established. The first issue of this publication appeared in January, 1957, and subsequent numbers have been published at intervals of two months. Much of the material that appears originally in this bulletin is subsequently reprinted in technical journals. It thus provides an effective medium for drawing attention to new developments.

The number of patents held by the Organization, and their use in manufacturing industry both in Australia and overseas, have greatly increased in recent years. The Industrial Research Liaison Section has been concerned in the development of effective arrangements for the licensing of these processes.

The Section attends to the many technical inquiries submitted to Head Office. Where appropriate these inquiries are sent on to specialists, either in the Organization or elsewhere. When this is not practicable replies are provided by the Section.

5. OVERSEAS LIAISON.

The Organization has Scientific Liaison Offices in London and Washington as constituent units of the British Commonwealth Scientific Office (London), and the British Commonwealth Scientific Office (North America). These Offices maintain close contact with overseas scientific developments and serve as centres for visitors and research students from the Organization and for other visiting scientists. The Chief Scientific Liaison Officers in London and Washington have represented Australia at scientific conferences in the United Kingdom, Europe, and the United States of America. The London Office has materially assisted in the recruitment of research staff from the United Kingdom and European countries.

6. FILM UNIT.

During the year the following films were completed and released:—

Supply and Drainage Ditches—16 mm., colour, sound, screening time 15 minutes. Produced in collaboration with the New South Wales Department of Agriculture, the film is concerned with the design, layout, and construction of an efficient supply and drainage ditch system for irrigation.

The Penguins of Macquarie Island—16 mm., colour, sound, screening time 13 minutes. The film was produced from record film material taken by members of the Australian National Antarctic Research Expedition and officers of C.S.I.R.O. on Macquarie Island; the life in the rookeries of the various species of penguins which visit the island to breed is described.

The Construction of Farm Dams—16 mm., colour, sound, screening time 13 minutes. The film was produced for the Water Conservation and Irrigation Commission of New South Wales, and shows the principles and methods recommended for dam construction.

The Mallee Fowl—16 mm., colour, sound, screening time 11 minutes. The film is compiled from unique record material taken in the field by an officer of the Wildlife Survey Section, and records the ingenious means used by the mallee fowl to maintain its eggs at a constant temperature of 92° F. in the mound of organic matter which it prepares for this purpose.

Spin Cooking—16 mm., b. and w., sound, screening time 9 minutes. Produced in collaboration with the Division of Food Preservation and Transport, the film is concerned with the behaviour of the solid contents of canned foods during sterilization and spin cooking under simulated conditions in plastic cans, and at various rates of spinning; high-speed cinematography was used to enable close inspection of movement within the cans.

Films on the following subjects are in the course of production:

Radio Astronomy in Australia—16 mm., colour, sound.
Mitosis—16 mm., colour, sound.
Pruning of Grape Vines—16 mm., colour, sound.
Solar Physics—16 mm., b. and w., sound.

Fifty-five prints of C.S.I.R.O. films have been distributed during the year and most of these were purchased by outside organizations. Two copies of all films were sent to the National Library in Canberra, and one copy to both the Australian Scientific Liaison Office in London and in Washington. Extra copies have been purchased by the National Library for exchange with overseas scientific bodies.

During the year a number of the Organization's films were screened at various film festivals:—

Edinburgh Film Festival—*The Mutton Birds of Bass Strait.*

International Scientific Film Congress, Vienna—
Two Blades of Grass.
The Mutton Birds of Bass Strait.
Meiosis.

Melbourne Film Festival—
Penguins of Macquarie Island.
The Mallee Fowl.

The Film Unit collaborated with national and commercial television stations in arranging and supplying film for television sessions.

XXXII. PERSONNEL OF COUNCIL AND COMMITTEES.

1. EXECUTIVE.

Sir Ian Clunies Ross, C.M.G., D.V.Sc., LL.D., F.A.A. (*Chairman*).

F. W. G. White, C.B.E., M.Sc., Ph.D. (*Deputy Chairman*).

S. H. Bastow, D.S.O., B.Sc., Ph.D. (*Chief Executive Officer*).

H. J. Goodes, O.B.E., B.A.

A. W. Coles.

2. ADVISORY COUNCIL.

Chairman.

Sir Ian Clunies Ross, C.M.G., D.V.Sc., LL.D., F.A.A.

Executive.

(See above.)

Chairmen of State Committees.

New South Wales—Professor H. R. Carne, D.V.Sc.
Victoria—Professor J. S. Turner, M.A., Ph.D., M.Sc., F.A.A.
Queensland—Professor W. V. Macfarlane, M.A., M.D.
South Australia—A. R. Callaghan, C.M.G., D.Phil., B.Sc., B.Sc.Agr.
Western Australia—Professor N. S. Bayliss, B.A., B.Sc., Ph.D., F.A.A.
Tasmania—T. A. Frankcomb.

Co-opted Members.

L. B. Bull, C.B.E., D.V.Sc., F.A.A.
Professor H. C. Forster, M.Agr.Sc., Ph.D.
D. R. Hawkes.
A. McCulloch, M.E.
D. Mackinnon.
I. M. McLennan, B.E.E.
Professor Sir Leslie Martin, C.B.E., Ph.D., F.A.A.
M. A. Mawby, D.Sc., F.S.T.C.
Professor M. L. Oliphant, M.A., Ph.D., D.Sc., LL.D., F.A.A., F.R.S.
W. W. Pettingell, B.Sc.
A. B. Ritchie, M.A.

E. P. S. Roberts.
W. J. Russell, A.C.I.A.
E. M. Schroder.
H. B. Somerset, M.Sc.
Professor A. D. Trendall, M.A., Litt.D.
J. V. Vernon, B.Sc., Ph.D.
C. M. Williams, O.B.E.

3. STATE COMMITTEES.

New South Wales.

Professor H. R. Carne, D.V.Sc. (*Chairman*).
Emeritus Professor Sir Henry Barraclough, K.B.E., V.D., B.E., M.M.E.
Professor J. P. Baxter, O.B.E., B.Sc., Ph.D., F.A.A.
F. S. Bradhurst, D.Sc.
J. N. Briton, B.Sc., B.E.
S. F. Cochran, F.A.S.A.
The Hon. O. McL. Falkiner, M.L.C.
W. R. Hebblewhite, B.E.
E. L. S. Hudson, Dip.For.
The Hon. Sir Norman Kater, M.L.C., M.B., Ch.M.
J. F. Litchfield.
Professor P. R. McMahon, M.Agr.Sc., Ph.D.
Professor J. R. A. McMillan, D.Sc.Agr., M.S.
Emeritus Professor Sir John Madsen, B.E., D.Sc., F.A.A.
J. Merrett.
C. St.J. Mulholland, B.Sc.
Professor D. M. Myers, B.Sc., D.Sc.Eng.
R. J. Noble, B.Sc.Agr., M.Sc., Ph.D.
R. P. Okeden.
J. G. Peake.
A. R. Penfold, A.S.T.C., F.R.A.C.I.
W. W. Pettingell, B.Sc.
Professor D. W. Phillips, B.Sc., Ph.D.
L. A. Pockley, B.V.Sc.
H. F. Prell.
Associate Professor F. H. Reuter, Ph.D.
T. C. Roughley, B.Sc.
Sir John Tivey, B.A., B.Sc., B.E.
J. Vernon, B.Sc., Ph.D.
Emeritus Professor W. L. Waterhouse, C.M.G., M.C., D.Sc.Agr., D.I.C., F.A.A.
Emeritus Professor R. D. Watt, M.A., B.Sc.
C. M. Williams, O.B.E.
A. J. Higgs, B.Sc. (Secretary).

Victoria.

Professor J. S. Turner, M.A., Ph.D., M.Sc., F.A.A. (*Chairman*).
R. S. Andrews, C.M.G., D.Sc., F.A.A.
D. T. Boyd, C.M.G.
L. B. Bull, C.B.E., D.V.Sc., F.A.A.
Sir Macfarlane Burnet, M.D., Ph.D., D.Sc., F.A.A., F.R.S.
G. A. Cook, O.B.E., M.C., M.Sc., B.M.E.
S. B. Dickinson, M.Sc.
Professor H. C. Forster M.Agr.Sc., Ph.D.
Professor J. N. Greenwood, D.Sc., M.Met.E.
Emeritus Professor E. J. Hartung, D.Sc.
H. Herman, D.Sc., M.M.E., B.C.E.
R. A. Hunt, D.S.O., B.C.E.
Associate Professor G. W. Leeper, M.Sc.
Emeritus Professor Sir Peter MacCallum, M.C., M.A., M.Sc., M.B., Ch.B.
D. Mackinnon.
I. M. McLennan, B.E.E.
Professor Sir Leslie Martin, C.B.E., Ph.D., F.A.A.
M. A. Mawby, D.Sc., F.S.T.C.
H. A. Mullett, I.S.O., B.Agr.Sc.
G. B. O'Malley, B.Met.E.
A. B. Ritchie, M.A.
Sir David Rivett, K.C.M.G., M.A., D.Sc., F.A.A., F.R.S.
D. E. Thomas, D.Sc.
Emeritus Professor Sir Samuel Wadham, M.A., LL.D., Dip.Agr.
W. E. Wainwright, A.S.A.S.M.
L. J. Weatherley, M.A.
Emeritus Professor H. A. Woodruff, B.Sc., M.R.C.S., L.R.C.P., M.R.C.V.S.
F. G. Nicholls, M.Sc. (*Secretary*).

Queensland.

Professor W. V. Macfarlane, M.A., M.D. (*Chairman*).
A. F. Bell, B.Sc., M.S.Agric., D.I.C.
Professor T. K. Ewer, B.V.Sc., Ph.D.
V. Greening.
W. A. Gunn, C.M.G.
R. L. Harrison.
Professor D. A. Herbert, D.Sc.
C. H. Jameson.
Professor T. G. H. Jones, D.Sc.
N. J. King.
A. McCulloch, M.E.
O. O. Madsen, M.L.A.
J. F. Meynink.
J. Michelmore.
I. W. Morley, B.M.E., B.Met.E.
O. E. J. Murphy, M.B., Ch.M.
E. P. S. Roberts.
Professor M. Shaw, M.E., M.Mech.E.
B. Flewell-Smith, M.M.
Professor W. Stephenson, B.Sc., Ph.D.
W. A. T. Summerville, D.Sc.
Professor L. J. H. Teakle, B.Sc.Agr., M.S., Ph.D.
S. A. Trout, M.Sc., Ph.D.
H. C. Urquhart, M.Sc.
R. Veitch, B.Sc.Agr., B.Sc.For.
Professor H. C. Webster, D.Sc., Ph.D.
W. Webster, B.V.Sc.
Professor F. T. M. White, B.Met.E., B.E. (Min.).
W. Young.
W. W. Bryan, M.Sc.Agr. (*Secretary*).

South Australia.

A. R. Callaghan, C.M.G., B.Sc., B.Sc.Agr., D.Phil. (*Chairman*).
A. J. Allen, F.R.A.C.I.
B. H. Bednall, B.Sc.
C. Haselgrove.
J. C. Hawker, B.A.
D. R. Hawkes.
O. H. Heinrich.
Professor L. G. H. Huxley, M.A., D.Phil., Ph.D., F.A.A.
R. N. McCulloch, M.B.E., D.Sc.Agr., B.Sc.
H. R. Marston, D.Sc., F.A.A., F.R.S.
Emeritus Professor Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.A.A., F.R.S.
Professor M. L. Mitchell, M.Sc.
F. W. Moorhouse, M.Sc.
The Hon. Sir Frank Perry, M.B.E., M.L.C.
Professor J. A. Prescott, C.B.E., D.Sc., F.A.A., F.R.S.
Professor E. A. Rudd, A.M., B.Sc.
W. L. Sanderson, O.B.E., M.C., C.de G.
E. M. Schroder.
A. M. Simpson, B.Sc.
Professor E. C. R. Spooner, B.E., D.Sc., D.Phil.
Professor J. G. Wood, Ph.D., D.Sc., F.A.A.
A. Packham, B.V.Sc. (*Secretary*).

Western Australia.

Professor N. S. Bayliss, B.A., B.Sc., Ph.D., F.A.A. (*Chairman*).
H. Bowley, F.R.A.C.I.
D. W. Brisbane, M.I.C.E., M.I. Struct. E., M.I.E.Aust.
C. R. Bunning, B.C.E.
Professor C. J. Birkett Clews, B.Sc., Ph.D.
Professor K. L. Cooper, B.Sc., M.A.
A. J. Fraser.
B. J. Grieve, M.Sc., Ph.D., D.I.C.
A. C. Harris, B.Sc.
G. K. Baron-Hay, M.C., B.Sc. (Agric.).

Sir Edward Lefroy.
A. A. McLeod, M.Aust.I.M.M., M.A.I.M.E.
B. Meecham.
Professor R. T Prider, B.Sc., Ph.D.
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F. J. Lehany, M.Sc., Division of Electrotechnology, C.S.I.R.O.
L. Lewis, B.Met.E., Industrial Research Liaison Section, C.S.I.R.O.
M. Lipson, B.Sc., Ph.D., Wool Textile Research Laboratory, Geelong, C.S.I.R.O.
F. G. Nicholls, M.Sc., C.S.I.R.O.
K. L. Sutherland, D.Sc., Ph.D., Division of Industrial Chemistry, C.S.I.R.O.
W. F. Evans, B.Sc., C.S.I.R.O. (*Secretary*).

30. C.S.I.R.O. STUDENTSHIP ADVISORY COMMITTEE.

S. H. Bastow, D.S.O., B.Sc., Ph.D., C.S.I.R.O. (*Chairman*).
Professor N. S. Bayliss, B.A., B.Sc., Ph.D., F.R.A.C.I., F.A.A., University of Western Australia.
Professor A L. McAulay, B.Sc., M.A., Ph.D., University of Tasmania.
Professor V. M. Trikojus, B.Sc., Ph.D., University of Melbourne.
Professor J. G. Wood, Ph.D., D.Sc., F.A.A., University of Adelaide.
D. T. C. Gillespie, M.Sc., C.S.I.R.O. (*Conjoint Secretary*).
W. M. Balding, B.Sc., C.S.I.R.O. (*Conjoint Secretary*).

31. FOUNDRY SANDS COMMITTEE.

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W. E. Ewers, M.Sc., Division of Industrial Chemistry, C.S.I.R.O.

32. FODDER CONSERVATION ADVISORY COMMITTEE.

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Dr. F. J. R. Hird, M.Ag.Sc., Ph.D., University of Melbourne.
W. L. Greenhill, M.E., Plant Fibre Section, C.S.I.R.O.
G. W. Lanigan, M.Sc., Plant Fibre Section, C.S.I.R.O.

33. FIBROUS PLASTER RESEARCH LIAISON COMMITTEE.

I. Langlands, M.Mech.E., B.E.E., Division of Building Research, C.S.I.R.O.
G. K. Condon, Associated Fibrous Plaster Manufacturers of Australia.
K. Hopkins, Associated Fibrous Plaster Manufacturers of Australia.

A. C. Mitchinson, Associated Fibrous Plaster Manufacturers of Australia.
M. J. Ridge, M.Sc., Division of Building Research, C.S.I.R.O.
E. A. Willis, M.L.A., Associated Fibrous Plaster Manufacturers of Australia.
J. R. Barned, B.Sc., Division of Building Research, C.S.I.R.O. (*Secretary*).

34. Paint on Plaster Research Committee.

I. Langlands, M.Mech.E., B.E.E., Division of Building Research, C.S.I.R.O.
A. E. Cameron, Chamber of Manufactures of New South Wales.
D. W. Griffiths, Victorian Chamber of Manufactures.
E. Haimann, Dr.Sc., Techn.Chem.E., Chamber of Manufactures of New South Wales.
J. Hesketh, F.R.A.C.I., Victorian Chamber of Manufactures.
E. Hoffmann, Dr.Phil., Division of Building Research, C.S.I.R.O.
J. R. Barned, B.Sc., Division of Building Research, C.S.I.R.O. (*Secretary*).

XXXIII. STAFF.

The following is a list of the staff of the Organization as at June 30, 1957. The list does not include clerical staff, typists, technical assistants, and miscellaneous workers.

1. Head Office.

(Head-quarters: 314 Albert-street, East Melbourne.)

Chairman—Sir Ian Clunies Ross, C.M.G., D.V.Sc., LL.D., F.A.A.
Deputy Chairman—F. W. G. White, C.B.E., M.Sc., Ph.D.
Chief Executive Officer—S. H. Bastow, D.S.O., B.Sc., Ph.D.
Research Secretary (Scientific Services)—F. G. Nicholls, M.Sc.
Research Secretary (Physical Sciences)—G. B. Gresford, B.Sc., A.R.M.T.C.
Research Secretary (Biological Sciences)—W. Ives, M.Ec.
Secretary (Finance and Supplies)—M. G. Grace, A.A.S.A.
Assistant Research Secretary (Staff)—D. T. C. Gillespie, M.Sc.
Assistant Research Secretary (Biological Sciences)—P. F. Butler, M.Ag.Sc.
Principal Research Officer—E. J. Drake, F.R.A.C.I.
Senior Research Officer—W. F. Evans, B.Sc.
Senior Research Officer—W. M. Balding, B.Sc.
Research Officer—B. E. Mummery, B.Sc.
Technical Officer—Miss J. Dunstone, B.Sc., Dip.Ed.
Technical Officer—I. D. Pullen, B.Sc.

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  Editor—N. S. Noble, D.Sc.Agr., M.S., D.I.C.
  Assistant Editor—A. E. Scott, M.Sc.
  Senior Research Officer—R. W. Crabtree, B.Sc.
  Senior Research Officer—Miss M. Walkom, B.A.
  Research Officer—L. A. Bennett, B.Sc.
  Research Officer—Miss L. F. Plunkett, B.Sc.
  Research Officer—G. J. Wylie, B.A.(Hons.), B.Sc.
  Senior Technical Officer—R. Schoenfeld, B.Sc.
  Technical Officer—R. L. Aujard, B.Sc.
  Technical Officer—G. A. Forster, B.A., B.Sc.

Library—
  Chief Librarian—Miss B. C. L. Doubleday, M.A.
  Librarian—Miss J. Conochie, B.Sc.
  Librarian—Miss L. J. Davey, B.Sc.
  Librarian—Miss I. J. McPhail, B.Sc., Dip.Ed. (at Brisbane).
  Librarian—Mrs. J. Barker, B.Sc.
  Librarian—Miss H. Storie, B.Sc., F.R.M.T.C.
  Librarian—Miss P. Prendergast, B.A.
  Union Catalogue of Periodicals, Editor—Miss A. L. Kent.

Accounts—
  Accountant—D. J. Bryant, A.A.S.A.

Finance—
  Assistant Secretary (Finance and Supplies)—R. W. Viney, A.A.S.A., A.C.I.S.

Stock Records—
  J. M. Short, A.A.S.A., A.C.I.S.

Orders and Transport—
  V. H. Leonard, J.P.

Staff—
  Staff Relations Officer—L. G. Peres, B.Ec.
  Senior Staff Officer—J. Coombe.

Records—
  P. Knuckey

Publications—
  Senior Technical Officer—T. R. Hunter.

Liaison Overseas—
 London—
  Chief Scientific Liaison Officer—A. Shavitsky, B.Agr.Sc.
  Senior Research Officer—A. B. Hackwell, B.Agr.Sc.
  Senior Research Officer—R. C. Richardson, B.E.
 Washington—
  Chief Scientific Liaison Officer—J. E. Cummins, B.Sc., M.S.
  Principal Research Officer—M. F. Day, B.Sc. (Hons.), Ph.D., F.A.A.

Translation Section—
  Senior Translator—A. L. Gunn.
  Senior Translator—E. Feigl, Ph.D.
  Senior Translator—F. P. Just, D.U.P.
  Senior Translator—Mrs. M. Slade.
  Translator—Miss M. J. Hardy, B.A. (Hons.).
  Translator—W. Wouters, Ph.D.(Lit.) (at Sydney).
  Translator—I. Zacopanay, B.A.(Agric.) (at Canberra).

Film Unit—
  Senior Research Officer—S. T. Evans, B.Sc.

Architectural—
  Architect—W. R. Ferguson, B.E.
  Draughtsman, Grade II.—A. S. Bhogal.

2. Secretaries of State Committees.

New South Wales—
  A. J. Higgs, B.Sc.(Hons.), Division of Radiophysics, University of Sydney.

Victoria—
  F. G. Nicholls, M.Sc., 314 Albert-street, East Melbourne.

Queensland—
  W. W. Bryan, M.Sc.Agr., Plant and Soils Laboratory, Brisbane.

South Australia—
  A. Packham, B.V.Sc., Division of Biochemistry and General Nutrition, University of Adelaide.

Western Australia—
  R. P. Roberts, M.Sc.(Agric.), Department of Agriculture, Perth.

Tasmania—
  D. Martin, D.Sc., " Stowell ", Stowell-avenue, Hobart.

3. Agricultural Research Liaison Section.

(Head-quarters: 314 Albert-street, East Melbourne.)

Acting Officer-in-charge—K. Loftus Hills, M.Agr.Sc.
Senior Research Officer—A. F. Gurnett-Smith, B.Agr.Sc.
Senior Research Officer—Mrs. J. Tully, B.Sc.(Hons.), Ph.D.
Principal Technical Officer—K. D. Woodyer, B.Sc.Agr.
Senior Technical Officer—R. N. Farquhar, B.Agr.Sc.
Senior Technical Officer—G. F. Smith, B.A.
Technical Officer—Miss B. M. Hall, B.Agr.Sc.
Technical Officer—J. J. Lenaghan, B.Agr.Sc. (abroad)).

4. ANIMAL GENETICS SECTION.

(Head-quarters: University of Sydney.)

Officer-in-charge—J. M. Rendel, B.Sc., Ph.D.
Principal Research Officer—A. S. Fraser, M.Sc., Ph.D.
Senior Research Officer—W. R. Sobey, B.Sc., Ph.D.
Senior Research Officer—G. W. Grigg, M.Sc., Ph.D.
Senior Research Officer—H. Hoffman, M.Sc., Ph.D.
Research Officer—D. F. Dowling, B.V.Sc., B.Sc., Ph.D.
Research Officer—B. L. Sheldon, B.Agr.Sc.(Hons.).
Research Officer—T. Nay.
Technical Officer—K. E. Turnbull, B.A.
Technical Officer—Miss L. H. Clarke, B.Sc.(Hons.).
Technical Officer—S. K. Stephenson, M.Sc.

5. DIVISION OF ANIMAL HEALTH AND PRODUCTION.

(Head-quarters: Cr. Flemington road and Park street, Parkville, Melbourne.)

At Divisional Head-quarters, Melbourne—

Chief—D. A. Gill, M.R.C.V.S., D.V.S.M.
Divisional Secretary—A. J. Vasey, B.Agr.Sc.

At Animal Health Research Laboratory—Melbourne—

Assistant Chief of Division and Officer-in-Charge—T. S. Gregory, D.V.Sc., Dip.Bact.
Assistant Chief of Division—A. W. Turner, O.B.E., D.Sc., D.V.Sc., F.A.A.
Laboratory Secretary—J. M. McMahon, B.Com.
Senior Research Fellow—L. B. Bull, C.B.E., D.V.Sc., F.A.A.
Senior Principal Research Officer—A. T. Dick, D.Sc.
Principal Research Officer—D. Murnane, D.V.Sc.
Principal Research Officer—R. H. Watson, D.Agr.Sc.
Senior Research Officer—A. T. Dann, M.Sc.
Senior Research Officer—J. E. Peterson, B.V.Sc.
Senior Research Officer—A. W. Rodwell, M.Sc., Ph.D.
Research Officer—J. B. Bingley, D.A.C.
Research Officer—G. S. Cottew, B.Sc.
Research Officer—Miss V. E. Hodgetts, B.Sc.
Research Officer—P. Plackett, B.A.
Research Officer—H. M. Radford, B.Sc.
Technical Officer—Miss C. E. Eales, B.Sc.
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Technical Officer—Miss E. M. Elder, B.Agr.Sc.
Technical Officer—J. R. Etheridge, Dip. Lab. Tech.
Technical Officer—N. E. Southern, Dip. Lab. Tech.
Technical Officer—J. J. Spencer, Dip. Lab. Tech.
Librarian—Miss F. V. Murray, M.Sc.

At Poultry Research Centre, Werribee, Victoria—

Principal Research Officer and Officer-in-charge—F. Skaller, M.Agr.Sc., B.Com.
Senior Research Officer—J. A. Morris, B.Sc.Agr. (Hons.), Ph.D.
Research Officer—T. E. Allen, B.Sc.
Research Officer—F. E. Binet, M.D. (Budapest).
Technical Officer—Miss L. W. Bobr, M.Sc.(Agr.) (Warsaw).

At McMaster Animal Health Laboratory, Sydney—

Officer-in-charge—D. F. Stewart, D.V.Sc., Dip.Bact.
Laboratory Secretary—H. H. Wilson.
William McIlrath Fellow in Animal Husbandry—M. C. Franklin, M.Sc., Ph.D.
Senior Principal Research Officer—H. McL. Gordon, B.V.Sc.
Principal Research Officer—Miss H. Newton Turner, B.Arch.
Senior Research Officer—N. P. H. Graham, B.V.Sc.
Senior Research Officer—Miss J. H. Koch, M.D.
Senior Research Officer—A. A. Dunlop, M.Agr.Sc., Ph.D.
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Research Officer—R. I. Sommerville, M.Agr.Sc. (Hons.).
Research Officer—P. K. Briggs, B.Sc.Agr.
Research Officer—A. W. H. Braden, M.Sc.
Research Officer—C. H. Gallagher, B.V.Sc., Ph.D.
Research Officer—I. G. Pearson, B.V.Sc.
Research Officer—L. E. A. Symons, B.V.Sc.
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Research Officer—J. H. Thomas, B.V.Sc.
Research Officer—B. A. Panaretto, B.V.Sc.
Ian McMaster Fellow—I. W. Parnell, B.A., Ph.D., F.R.S.E.
Technical Officer—F. J. Hamilton.
Technical Officer—H. V. Whitlock, Cert. Lab. Tech.
Technical Officer—G. C. Merritt, Cert. Lab. Tech.
Technical Officer—B. L. Campbell, A.S.T.C.
Technical Officer—K. J. Farrington, B.Sc., A.S.T.C.
Technical Officer—J. C. Boray, D.V.M. (Budapest).
Technical Officer—Miss M. J. Heidman, B.A.
Librarian—Miss A. G. Culey, M.Sc.

At Sheep Biology Laboratory, Prospect, New South Wales—

Asssistant Chief of Division and Officer-in-charge—I. W. McDonald, B.V.Sc., B.Sc., Ph.D.
Technical Secretary—J. H. Elliott, B.Sc.(Hons.).
Principal Research Officer—P. G. Schinckel, B.V.Sc.
Principal Research Officer—K. A. Ferguson, B.V.Sc., Ph.D.
Principal Research Officer—R. L. Reid, B.Sc.Agr. (Hons.), Ph.D.
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Senior Research Officer—G. Alexander, M.Agr.Sc.
Senior Research Officer—A. M. Downes, M.Sc.
Senior Research Officer—L. T. Wilson, B.Sc.
Senior Research Officer—B. F. Short, M.Agr.Sc., Ph.D.
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Research Officer—R. H. Weston, B.Sc.Agr.(Hons.).
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Research Officer—A. C. Warner, B.Sc., Dip. Microbiol., Ph.D.
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Technical Officer—W. T. Outch, A.S.T.C.
Technical Officer—C. Mills, A.S.T.C.
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Technical Officer—Miss J. Quigan, B.Agr.Sc.
Technical Officer—Miss B. Burnet, B.Agr.Sc.
Technical Officer—Miss S. Kemeny, B.Agr.Sc.
Technical Officer—J. W. Bennett, B.Sc.

At Regional Pastoral Laboratory, Armidale, New South Wales—

Executive Officer to Research Committee—J. F. Barrett, B.V.Sc., H.D.A.
Senior Research Officer—W. H. Southcott, B.V.Sc.
Senior Research Officer—L. J. Lambourne, M.Sc.
Senior Technical Officer—J. M. George, B.Agr.Sc.

At F. D. McMaster Field Station, Badgery's Creek, New South Wales—

Officer-in-charge—R. H. Hayman, M.Agr.Sc.
Research Officer—D. F. Dowling, B.V.Sc., B.Sc., Ph.D.
Research Officer—J. M. Doney, B.Sc.(Hons.), Ph.D.
Technical Officer—Y. S. Pan, B.Sc.Agr.

At Veterinary Parasitology Laboratory, Yeerongpilly, Queensland—
Officer-in-charge—F. H. S. Roberts, D.Sc.
Senior Research Officer—R. F. Riek, B.V.Sc., M.Sc.
Senior Research Officer—P. H. Durie, M.Sc.
Research Officer—K. C. Bremner, M.Sc.
Technical Officer—R. K. Keith, Dip.Ind.Chem.

At National Field Station, " Gilruth Plains ", Cunnamulla, Queensland—
Officer-in-charge—C. H. S. Dolling, B.Ag.Sc., R.D.A.
Technical Officer—R. W. Moore, B.Ag.Sc.

At National Cattle Breeding Station, " Belmont ", Rockhampton, Queensland—
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Senior Research Officer—H. G. Turner, B.Agr.Sc., M.A.
Senior Technical Officer—G. French, B.V.Sc.
Technical Officer—A. V. Schleger, B.Sc.

At Western Australian Department of Agriculture, Animal Health and Nutrition Laboratory, Nedlands, Western Australia—
Senior Research Officer—A. B. Beck, M.Sc.

At Institute of Agriculture, University of Western Australia, Nedlands, Western Australia—
Senior Research Officer—E. Munch-Petersen, M.Sc., B.A.

6. DIVISION OF BIOCHEMISTRY AND GENERAL NUTRITION.

(Head-quarters: University of Adelaide.)

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Technical Secretary—A. Packham, B.V.Sc., A.A.SA.
Senior Principal Research Officer—D. S. Riceman, M.Sc., B.Ag.Sc.
Principal Research Officer—Miss M. C. Dawbarn, M.Sc.
Principal Research Officer—F. V. Gray, M.Sc.
Principal Research Officer—I. G. Jarrett, M.Sc.
Principal Research Officer—H. J. Lee, M.Sc.
Principal Research Officer—J. A. Mills, Ph.D., M.Sc.
Principal Research Officer—A. W. Peirce, D.Sc.
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Senior Research Officer—G. B. Jones, M.Sc.
Senior Research Officer—A. F. Pilgrim, B.Sc.
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Research Officer—R. E. Kuchel, B.Sc., R.D.A.
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Research Officer—Mrs. D. C. Roder, M.Sc.
Research Officer—R. M. Smith, B.Sc.
Research Officer—R. A. Weller, B.Sc.
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Senior Technical Officer—R. Hewett Jones, R.D.A.
Senior Technical Officer—V. A. Stephen.
Technical Officer—A. C. Blaskett, B.Sc.
Technical Officer—O. H. Filsell, B.Sc.
Technical Officer—W. S. Osborne-White, B.Sc.
Technical Officer—J. O. Wilson (part-time).

7. DIVISION OF BUILDING RESEARCH.

(Head-quarters: Graham-road, Highett, Victoria.)

Administration—
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Technical Secretary—J. R. Barned, B.Sc.
Editor—I. C. H. Croll, B.Sc.
Sectional Draughtsman—W. Maier, Dip.Ing.

Information and Library—
Senior Research Officer—R. C. McTaggart, B.Sc.
Principal Technical Officer—E. M. Coulter, M.Agr.Sc.
Librarian—Miss L. W. Power.

Mechanics and Physics of Materials—
Senior Research Officer—F. A. Blakey, B.E.(Hons.), Ph.D.
Research Officer—L. Finch, B.Arch., B.Sc., Ph.D.
Principal Technical Officer—W. H. Taylor, M.C.E.
Senior Technical Officer—R. E. Lewis, B.Sc.(Hons.).
Senior Technical Officer—E. N. Mattison.
Senior Technical Officer—B. Kroone, D.R.S.
Technical Officer—F. D. Beresford, F.R.M.T.C.
Technical Officer—J. J. Russell, B.Sc.
Technical Officer—D. R. Moorehead, A.R.M.T.C.

Masonry Investigations—
Principal Research Officer—J. S. Hosking, M.Sc., Ph.D.
Principal Research Officer—W. F. Cole, M.Sc., Ph.D.
Senior Research Officer—H. V. Hueber, Dr. Phil.
Senior Research Officer—R. D. Hill, B.Sc.(Hons.), B.Com.
Research Officer—Mrs. T. Demediuk, Dr. Phil. Nat.
Research Officer—Miss A. A. Milne, B.Sc.(Hons.), Ph.D.
Technical Officer—Miss M. E. Neilson, B.Sc.
Technical Officer—Miss N. M. Rowland, F.M.T.C.
Technical Officer—A. E. Holland, A.M.T.C.
Technical Officer—D. N. Crook, A.S.T.C.
Technical Officer—C. L. Carrel, B.Sc.

Surfacing Materials Investigations—
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Research Officer—J. E. Bright, B.Sc.
Senior Technical Officer—D. A. Powell, B.Sc.
Technical Officer—G. F. Moss, B.Sc.
Technical Officer—S. J. Way, B.Sc.

Architectural Physics—
Principal Research Officer—R. W. Muncey, M.E.E.
Senior Research Officer—W. K. R. Lippert, Dr.rer.nat.
Senior Research Officer—A. F. B. Nickson, M.Sc.
Research Officer—T. S. Holden, B.Sc.
Technical Officer—P. Dubout, B.Sc.
Technical Officer—W. A. Davern, A.R.M.T.C.

Waterproofing Investigations—
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Research Officer—K. G. Martin, B.Sc.(Hons.).
Senior Technical Officer—J. W. Spencer, B.Sc.
Technical Officer—N. G. Brown, A.M.T.C.

Fibrous Plaster Research—
Senior Research Officer—M. J. Ridge, M.Sc.

Paint on Plaster Investigations—
Senior Research Officer—E. Hoffmann, Dr.Phil.

8. CANBERRA LABORATORIES, ADMINISTRATIVE OFFICE.

(The services of this office are common to the Divisions and Sections in Canberra.)

Chief Clerk—K. J. Prowse.
Deputy Chief Clerk—D. Banyard.
Accountant—E. E. Petersen.
Librarian—D. R. May, B.A., B.Sc.
Librarian—Miss C. I. Beikoff, B.A.

9. COAL RESEARCH SECTION.

(Head-quarters: Delhi-road, North Ryde, New South Wales.)

Officer-in-charge—H. R. Brown, B.Sc.(Eng.) (Hons.).
Technical Secretary—K. F. Baker, M.Sc.Appl., D.Sc.Tech.
Principal Research Officer—J. D. Brooks, B.Sc.(Hons.).
Principal Research Officer—N. Y. Kirov, M.Sc.
Principal Research Officer—P. L. Waters, B.Sc.(Hons.), Ph.D.
Senior Research Officer—W. T. Cooper, B.Sc.(Hons.), Dip.Ed.
Senior Research Officer—R. A. Durie, M.Sc., Ph.D.

Senior Research Officer—E. J. Greenhow, B.Sc.(Hons.), Ph.D.
Senior Research Officer—E. J. Greenhow, B.Sc.(Hons.),
Senior Research Officer—G. L. Shires, M.E.
Research Officer—J. J. Batten, M.Sc. (on overseas studentship).
Research Officer—K. McG. Bowling, B.Sc.(Hons.), Ph.D.
Research Officer—A. Cameron, B.Sc.(Hons.).
Research Officer—M. Kossenberg, Ph.D.
Research Officer—J. S. Shannon, B.Sc.(Hons.), Ph.D.
Research Officer—J. F. Stephens, M.Sc. (on overseas studentship).
Research Officer—S. Sternhell, M.Sc.
Research Officer—G. H. Taylor, M.Sc., Dr.rer.nat.
Principal Technical Officer—M. S. Burns, M.Inst.F.
Senior Technical Officer—F. Agus, A.M.Inst.F.
Senior Technical Officer—G. à Donau Szpindler, Dipl. Ing., D.I.C.
Senior Technical Officer—J. P. F. Hennelly, B.Sc.
Senior Technical Officer—R. H. Jones, B.Sc.(Hons.).
Senior Technical Officer—J. W. Smith, A.R.I.C.
Senior Technical Officer—J. N. Stephens, M.A.
Senior Technical Officer—J. W. Sweeting, B.Sc.
Senior Technical Officer—J. Szewczyk, Dipl.Ing.Chem.
Senior Technical Officer—A. Watts, A.S.M.B.
Technical Officer—P. R. C. Goard, B.Sc.
Technical Officer—Miss R. E. Lack, B.Sc.
Technical Officer—Mrs. O. V. Molnar, Dipl.Chem.Eng.
Technical Officer—R. Neronowicz, Dipl.Eng.
Technical Officer—D. H. Philipp, B.Sc.
Technical Officer—H. N. S. Schafer, B.Sc.(Hons.).
Technical Officer—W. O. Stacy, B.Sc.
Technical Officer—S. St. J. Warne, B.Sc.
Technical Officer—Mrs. P. White, B.Sc.
Librarian—Miss A. W. Johns, B.A.(Hons.), Dip.Ed.

10. Dairy Research Section.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-charge—G. Loftus Hills, B.Agr.Sc.
Laboratory Secretary—A. K. Klingender, B.Sc.
Principal Research Officer—N. King, M.Sc.
Senior Research Officer—E. G. Pont, M.Sc.Agr.
Senior Research Officer—K. Kumetat, Dr.Phil.
Senior Research Officer—J. Conochie, B.Sc.(Agric.).
Senior Research Officer—J. Czulak, B.Sc.(Agric.), Dip. Bact.
Senior Research Officer—D. A. Forss, M.Sc.
Research Officer—J. W. Lee, B.Sc.(Hons.) (on leave).
Senior Technical Officer—A. J. Lawrence, B.Sc.
Senior Technical Officer—Miss B. M. P. Keogh, M.Sc.
Technical Officer—R. Beeby, A.R.M.T.C.

11. Division of Electrotechnology.

(Head-quarters: National Standards Laboratory at the University of Sydney.)

Chief—F. J. Lehany, M.Sc.
Technical Secretary—R. C. Richardson, B.E. (seconded to A.S.L.O., London).
Senior Principal Research Officer—W. K. Clothier, B.Sc., M.E.
Senior Principal Research Officer—A. M. Thompson, B.Sc.(Hons.).
Principal Research Officer—R. J. Meakins, B.Sc., Ph.D., D.I.C.
Principal Research Officer—D. L. Hollway, B.E.E., M.Eng.Sc., D.Sc.(Eng.).
Senior Research Officer—L. G. Dobbie, M.E.
Senior Research Officer—J. S. Dryden, M.Sc., Ph.D., D.I.C.
Senior Research Officer—T. M. Palmer, Dipl.F.H.
Senior Research Officer—L. Medina, Dipl.Ing.
Senior Research Officer—D. L. H. Gibbings, B.E., B.Sc., Ph.D.
Senior Research Officer—J. J. O'Dwyer, B.Sc., B.E., Ph.D.

Senior Research Officer—D. W. Posener, M.Sc., Ph.D.
Research Officer—D. G. Lampard, M.Sc., Ph.D.
Research Officer—H. K. Welsh, M.Sc.
Research Officer—G. J. A. Cassidy, B.E.E.
Research Officer—G. J. Johnson, B.Sc.(Hons.).
Research Officer—P. G. Harper, B.Sc.(Hons.), Ph.D.
Research Officer—W. E. Smith, B.Sc.(Hons.).
Principal Technical Officer—L. M. Mandl, Dipl.Ing., A.S.T.C.
Principal Technical Officer—H. A. Smith, A.S.T.C.
Senior Technical Officer—R. W. Archer, A.S.T.C.
Senior Technical Officer—F. C. Brown, A.S.T.C.
Senior Technical Officer—M. C. McGregor, A.S.T.C.
Senior Technical Officer—I. K. Harvey, A.S.T.C.
Senior Technical Officer—D. B. Armitage, B.Sc., B.E.
Technical Officer—H. Bairnsfather.
Technical Officer—H. C. Collins, A.S.T.C.
Technical Officer—J. M. Melano, A.S.T.C.
Technical Officer—J. S. Cook, M.Sc.
Technical Officer—R. E. Holmes, A.S.T.C.
Technical Officer—R. P. Hoffman, A.S.T.C.
Technical Officer—P. Buss, A.S.T.C.
Technical Officer—R. C. Colgan, B.E.E., A.R.M.T.C.
Technical Officer—F. P. Kelly, A.S.T.C.
Technical Officer—M. J. Stewart, A.S.T.C.

12. Engineering Section.

(Head-quarters: Explosives Factory, Maribyrnong, Victoria.)

Officer-in-charge—R. N. Morse, B.Sc., B.E.
Electrical and Mechanical Engineer—F. G. Hogg, B.E.
Senior Research Officer—J. J. Kowalczewski, Dipl.Ing.
Research Officer—M. G. Kovarik, Dipl.Ing.
Research Officer—I. P. Arthur, B.Mech.E.
Principal Technical Officer—K. A. Robeson, B.Mech.E.
Chief Draughtsman—G. T. Stephens, Dip.Mech.Eng., Dip.Elec.Eng.
Senior Technical Officer—J. T. Czarnecki, Dipl.Ing.
Senior Technical Officer—D. W. Cunliffe, F.R.M.T.C.
Senior Technical Officer—W. R. Read.
Senior Technical Officer—R. H. S. Riordan, B.E.E.
Technical Officer—T. D. Norwood, Dip.Mech.Eng., Dip. Elec.Eng.
Draughtsman, Grade II.—E. T. Davey.
Draughtsman, Grade II.—D. H. Lee.
Draughtsman, Grade II.—H. L. Chapman.

13. Division of Entomology.

(Head-quarters: Canberra, A.C.T.)

At Canberra—

Administration—
Chief—A. J. Nicholson, D.Sc., F.A.A.
Asistant Chief—D. F. Waterhouse, D.Sc., F.A.A.
Technical Secretary—K. L. Taylor, B.Sc.Agr.

Population Dynamics—
Chief of Diviison—A. J. Nicholson, D.Sc., F.A.A.
Senior Technical Officer—A. T. Mills.

Field Population Studies—
Principal Research Officer—L. R. Clark, M.Sc.

Termite Investigations—
Principal Research Officer—F. J. Gay, B.Sc., D.I.C.

Locust and Grasshopper Investigations—
Principal Research Officer—K. H. L. Key, M.Sc., Ph.D., D.I.C.
Technical Officer—L. J. Chinnick, R.D.A.

Miscellaneous Grasshopper Investigations—
Research Officer—D. P. Clark, B.Sc.(Hons.), Ph.D.

Biological Control—
Principal Research Officer—F. Wilson.
Research Officer—G. F. Bornemissza, Ph.D.
Research Officer—Mrs. M. Carver, B.Sc., Ph.D.
Technical Officer—A. Magassy, Dr.Agr.Sc. (Budapest).

Insecticide Investigations—
Senior Research Officer—R. W. Kerr, B.Sc.
Physiology and Toxicology—
Assistant Chief—D. F. Waterhouse, D.Sc., F.A.A.
Principal Research Officer—D. Gilmour, M.Sc.
Principal Research Officer—R. H. Hackman, M.Sc., Ph.D.
Senior Research Officer—R. F. Powning, A.S.T.C., M.Sc.
Research Officer—L. B. Barton Browne, B.Sc. (Hons.), Ph.D.
Research Officer—A. R. Gilby, M.Sc., Ph.D. (studentship leave).
Senior Technical Officer—H. Irzykiewicz.
Technical Officer—Mrs. M. M. Goldberg, B.Sc.
Taxonomy of Diptera—
Senior Research Officer—S. J. Paramonov, D.Sc.
Museum—
Research Officer—T. G. Campbell.
Virus Vector Investigations—
Principal Research Officer—M. F. Day, B.Sc.(Hons.), Ph.D., F.A.A. (seconded to A.S.L.O., Washington).
Research Officer—T. D. C. Grace, B.Sc.(Hons), (studentship leave).
Senior Techncial Officer—N. E. Grylls, D.D.A.
Cockchafer Investigations—
Senior Research Officer—P. B. Carne, B.Agr.Sc., Ph.D., D.I.C.
Ant Investigations—
Senior Research Officer—T. Greaves.
Pasture Caterpillar Investigations—
Principal Research Officer—I. F. B. Common, M.A., M.Agr.Sc.
Stored Products Pests Investigations—
Principal Research Officer—S. W. Bailey, B.Sc., A.R.C.S.
Potato Moth and Taxonomy of Hymenoptera—
Senior Research Officer—E. F. Riek, M.Sc.
Sheep Blowfly Ecology—
Principal Research Officer—K. R. Norris, M.Sc.
Ecology of Orchard Pests—
Senior Research Officer—P. Geier, B.Sc.(Agr.), Ph.D. (abroad).

At Yeerongpilly, Queensland—
Cattle Tick Investigations—
Senior Research Officer—P. R. Wilkinson, M.A.
Senior Research Officer—W. J. Roulston, B.Sc.
Technical Officer—R. A. J. Meyers, Q.D.A.H., Q.D.D.
Technical Officer—H. Schnitzerling, Dip.Ind.Chem.
Technical Officer—B. F. Stone, Dip.Ind.Chem.
Technical Officer—C. A. Schuntner, B.Sc.

At Nedlands, Western Australia—
Earth Mite and Lucerne Flea Investigations—
Senior Research Officer—M. M. H. Wallace, B.Sc. (Hons.).
Technical Officer—J. A. Mahon, Dip.D.Sci.

At Sydney—
Biological Control—
Senior Research Officer—G. J. Snowball, B.Sc. (Hons.).
Technical Officer—R. G. Lukins, B.Sc.
Fruit Fly Ecology (*with University of Sydney*)—
Research Officer—M. A. Bateman, B.Sc.(Hons.).

14. DIVISION OF FISHERIES AND OCEANOGRAPHY.

(Head-quarters: Cronulla, New South Wales.)

At Cronulla—
Chief—G. F. Humphrey, M.Sc., Ph.D.
Technical Secretary—Mrs. L. M. Willings, B.A. (Hons.), Dip.Ed.
Librarian—Miss A. M. Copeland, B.A.(Hons.).
Research Fellow—L. G. M. Baas Becking, Ph.D., D.Sc.
Principal Research Officer—B. V. Hamon, B.Sc. (Hons.), B.E.(Hons.).
Principal Research Officer—D. J. Rochford, B.Sc. (Hons.).
Principal Research Officer—E. J. F. Wood, B.A., M.Sc.
Senior Research Officer—I. S. R. Munro, M.Sc.
Senior Research Officer—J. M. Thomson, M.Sc.
Research Officer—R. G. Chittleborough, M.Sc., Ph.D.
Research Officer—T. R. Cowper, B.Sc.(Hons.).
Research Officer—W. Dall, M.Sc.
Research Officer—R. W. George, B.Sc.(Hons.) (study leave).
Research Officer—D. E. Kurth, B.Sc.(Hons.).
Research Officer—R. J. MacIntyre, M.Sc.
Research Officer—W. B. Malcolm, B.Sc., Ph.D. (overseas).
Research Officer—J. P. Robins, B.Sc.
Research Officer—R. S. Spencer, B.Sc. (Hons.).
Research Officer—H. B. Wisely, M.Sc.
Technical Officer—N. L. Brown, A.S.T.C.
Technical Officer—Miss B. B. Dew, B.A.
Technical Officer—D. J. Dunstan, B.Sc.
Technical Officer—H. R. Jitts, B.Sc.
Technical Officer—D. J. Tranter, B.Sc.
Technical Officer—C. Walker, M. Pharm.

At Melbourne—
Technical Officer—P. E. Gartner, M.C., B.Sc.

At Perth—
Senior Research Officer—K. Sheard, D.Sc.

At Hobart—
Senior Research Officer—A. G. Nicholls, B.Sc. (Hons.), Ph.D.
Senior Research Officer—A. M. Olsen, M.Sc.
Research Officer—A. H. Weatherley, B.Sc.

At Thursday Island, Queensland—
Research Officer—J. S. Hynd, B.Sc.(Hons.).

15. DIVISION OF FOOD PRESERVATION AND TRANSPORT.

(Head-quarters: State Abattoir, Homebush Bay, New South Wales).

At Homebush, New South Wales—
Administration and General—
Chief—J. R. Vickery, M.Sc., Ph.D.
Technical Secretary—R. B. Withers, M.Sc., Dip.Ed.
Senior Librarian—Miss B. Johnston, B.Sc.
Librarian—Mrs. C. E. C. Salter.
Senior Technical Officer—K. M. Digby, A.S.T.C., A.R.A.I.A.
Technical Officer—Miss E. M. Christie, B.Sc.

Physics and Transport Section—
Senior Principal Research Officer—E. W. Hicks, B.A., B.Sc.
Senior Research Officer—M. C. Taylor, M.Sc.
Research Officer—H. L. Evans, M.Sc.
Technical Officer—M. K. Kelly, B.Sc.

Microbiology Section—
Senior Principal Research Officer—W. J. Scott, B.Agr.Sc., D.Sc.
Senior Research Officer—W. G. Murrell, B.Sc.Agr., D.Phil.
Research Officer—J. H. B. Christian, B.Sc.Agr. (Hons.), Ph.D.
Research Officer—R. H. Leach, M.Sc., D.Phil.
Senior Technical Officer—D. F. Ohye, D.I.C.
Technical Officer—Miss B. J. Marshall, A.S.T.C. (overseas).
Technical Officer—Miss K. M. Smith, B.Sc.
Technical Officer—Miss P. A. Maw, B.Sc.

Biochemistry Investigations—
Principal Research Officer—F. E. Huelin, B.Sc. (Hons.), Ph.D.
Research Officer—J. B. Davenport, M.Sc.
Technical Officer—B. H. Kennett, A.S.T.C.

Organic Chemistry Investigations—
Senior Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil.
Senior Research Officer—E. F. L. J. Anet, M.Sc., Ph.D. (overseas).
Research Officer—D. L. Ingles, M.Sc., Ph.D.
Technical Officer—W. D. Johnson, M.Sc.

Fruit and Vegetable Storage Section—
Senior Research Officer—E. G. Hall, B.Agr.Sc. (Hons.)
Research Officer—Miss J. M. Bain, M.Sc.
Research Officer—K. J. Scott, B.Agr.Sc., Dip.Ed. (New South Wales Department of Agriculture).
Technical Officer—T. J. Riley, H.D.A.

Canning and Fruit Products Section—
Senior Principal Research Officer—L. J. Lynch, B.Agr.Sc. (Hons.).
Principal Research Officer—J. F. Kefford, M.Sc.
Senior Research Officer—R. S. Mitchell, M.Agr.Sc.
Research Officer—B. V. Chandler, B.Sc. (Hons.) (overseas).
Research Officer—E. G. Davis, B.Sc. (Hons.).
Research Officer—P. W. Board, B.Sc. (Hons.).
Research Officer—D. J. Casimir, M.Sc., Dip.Ed.
Technical Officer—K. A. Harper, B.Sc., A.S.T.C.

Dried Foods Section—
Research Officer—D. McG. McBean, B.Sc.
Technical Officer—A. A. Johnson, A.S.T.C.

Fish Preservation Investigations—
Principal Research Officer—W. A. Empey, B.V.Sc.
Technical Officer—W. A. Montgomery, A.S.T.C.

Egg Investigations—
Chief—J. R. Vickery, M.Sc., Ph.D.
Senior Technical Officer—F. S. Shenstone, A.S.T.C.

Freezing of Fruit and Vegetables—
Research Officer—S. M. Sykes, B.Agr.Sc. (New South Wales Department of Agriculture).
Research Officer—I. J. Tinsley, B.Sc. (Hons.), M.S. (overseas).
Research Officer—J. H. Scheltema, Ing.Agr.
Technical Officer—J. H. Last, A.S.T.C.

At Auburn, New South Wales—
Meat Dehydration Investigations—
Senior Research Officer—A. R. Prater, B.Sc.Agr.

At Botany School, University of Sydney—
Plant Physiology Investigations—
Chief Research Officer—R. N. Robertson, B.Sc. (Hons.), Ph.D., F.A.A.
Senior Research Officer—H. S. McKee, B.A., D.Phil.
Senior Research Officer—J. F. Turner, M.Sc., Ph.D.
Senior Research Officer—Mrs. D. H. Turner, M.Sc., Ph.D.
Research Officer—A. B. Hope, B.Sc., Ph.D. (overseas).
Research Officer—M. D. Hatch, B.Sc. (Hons.).
Technical Officer—N. F. B. Tobin, B.Sc.
Technical Officer—J. Smydzuk, Ing. of Ch.
Technical Officer—J. B. Lee, B.Sc.

At Botany School, University of Melbourne—
Plant Physiology Investigations—
Senior Research Officer—K. S. Rowan, M.Sc., Ph.D.

At Biochemistry School, University of Sydney—
Physical Chemistry Section—
Senior Research Officer—H. A. McKenzie, M.Sc., Ph.D.
Research Officer—J. J. Macfarlane, M.Sc. (overseas).
Senior Technical Officer—M. B. Smith, A.S.A.S.M., B.Sc.
Technical Officer—Miss J. F. Back, B.Sc., Dip.Ed.

At Tasmanian Regional Laboratory, Hobart—
Canning and Fruit Products—
Senior Technical Officer—R. A. Gallop, A.S.T.C.

At Cannon Hill, Queensland—
Meat Investigations—
Officer-in-charge—A. Howard, M.Sc.
Senior Research Officer—G. Kaess, Dr. Ing.
Technical Officer—N. T. Russell, D.I.C.
Technical Officer—M. F. Meaney, B.Sc. (Hons.).
Technical Officer—P. E. Bouton, B.Sc.
Technical Officer—J. F. Weidemann, B.Sc.
Technical Officer—D. R. Davy, B.Sc. (Hons.).

16. Division of Forest Products.

(Head-quarters: 69 Yarra Bank-road, South Melbourne, Victoria.)

Administration—
Chief—S. A. Clarke, B.E.
Assistant Chief—C. S. Elliot, B.Sc.
Assistant Chief—H. E. Dadswell, D.Sc.
Technical Secretary—F. A. Priest, A.S.A.S.M.
Research Officer—A. P. Wymond, M.Sc.
Senior Librarian—Miss M. I. Hulme.
Librarian—Miss A. Forbes.
Principal Technical Officer—L. Santer, M.Mech.E., Dip.Eng.
Draughtsman, Grade II.—R. R. Henderson.

Wood and Fibre Structure Section—
Chief Research Officer-in-charge—H. E. Dadswell, D.Sc.
Principal Research Officer—A. B. Wardrop, M.Sc., Ph.D.
Senior Research Officer—Miss M. M. Chattaway, M.A., B.Sc., D.Phil.
Senior Research Officer—W. E. Hillis, M.Sc., A.G.Inst.Tech.
Senior Research Officer—H. D. Ingle, B.For.Sc.
Research Officer—J. Cronshaw, B.Sc.(Hons.), Ph.D.
Senior Technical Officer—J. W. P. Nicholls, B.Sc.
Technical Officer—Miss A. Carle, B.Sc., A.G.Inst.Tech.
Technical Officer—G. W. Davies, B.Sc.

Wood Chemistry Section—
Senior Principal Research Officer—W. E. Cohen, D.Sc.
Principal Research Officer—D. E. Bland, M.Sc.
Principal Research Officer—H. G. Higgins, B.Sc.(Hons.).
Senior Research Officer—R. C. McK. Stewart, B.Sc.
Senior Research Officer—A. J. Watson, A.R.M.T.C.
Research Officer—Mrs. J. Kottek, B.Sc.(Hons.).
Senior Technical Officer—Miss G. Schwerin, B.Sc.
Senior Technical Officer—J. L. de Yong, B.Sc.
Technical Officer—Miss Y. Greet, B.Sc.
Technical Officer—Miss V. Goldsmith, A.R.M.T.C.
Technical Officer—A. W. McKenzie, A.R.M.T.C.

Timber Physics Section—
Principal Research Officer-in-charge—R. S. T. Kingston, B.Sc., B.E.
Senior Research Officer—G. N. Christensen, M.Sc., Ph.D.
Senior Research Officer—L. N. Clarke, M.Mech.E., B.Eng.Sc.
Research Officer—Miss K. E. Kelsey, M.Sc.
Senior Technical Officer—L. D. Armstrong, A.R.M.T.C.
Senior Technical Officer—D. R. L. Callow, B.E. (on leave).
Senior Technical Officer—N. C. Edwards, A.S.M.B.
Senior Technical Officer—P. U. A. Grossman, M.Sc., Ph.A.Mr. (on leave).
Technical Officer—Mrs. C. J. E. Risdon, A.R.M.T.C.
Technical Officer—J. Rozulapa, Dip.Phys.

Timber Mechanics Section—

Principal Research Officer-in-charge—J. D. Boyd, M.C.E.
Principal Research Officer—N. H. Kloot, M.Sc.
Senior Research Officer—R. G. Pearson, B.A., B.C.E.
Senior Technical Officer—R. N. Bournon.
Senior Technical Officer—J. J. Mack, A.R.M.T.C.
Technical Officer—Miss A. Ryan, A.R.M.T.C.
Technical Officer—K. B. Schuster, A.R.M.T.C.

Timber Preservation Section—

Senior Principal Research Officer-in-charge—N. Tamblyn, M.Sc.(Agric.)
Senior Research Officer—E. W. B. Da Costa, M.Agr.Sc.
Senior Research Officer—E. L. Ellwood, B.Sc.For., M.Sc., Ph.D. (on leave).
Senior Research Officer—R. Johanson, M.Sc.
Research Officer—P. Rudma, B.Sc., Ph.D., Dip.Microbiol.
Principal Technical Officer—F. A. Dale, A.R.M.T.C.
Principal Technical Officer—J. Beesley, M.Sc.(For.), Dip.For.
Senior Technical Officer—N. E. M. Walters, B.Sc.
Technical Officer—Miss F. J. Lloyd, B.Sc.
Technical Officer—D. F. McCarthy, A.R.M.T.C.

Timber Seasoning Section—

Senior Principal Research Officer-in-charge—G. W. Wright, M.E.
Research Officer—W. G. Kauman, B.Sc., A.R.M.T.C. (on study leave).
Senior Technical Officer—L. J. Brennan.
Senior Technical Officer—G. S. Campbell.
Senior Technical Officer—F. J. Christensen, A.R.M.T.C.
Technical Officer—R. Finighan, A.R.M.T.C.
Technical Officer—R. Liversidge, A.R.M.T.C.
Draughtsman, Grade II.—K. W. Fricke, Assoc. Aero.Eng.

Plywood Investigations Section—

Principal Research Officer-in-charge—J. W. Gottstein, B.Sc.
Senior Technical Officer—K. Hirst.
Technical Officer—P. J. Moglia, Dip.Mech.Eng.
Technical Officer—A. Stashevski, Dip.For.Eng., E.T.H.

Timber Utilization Section—

Senior Principal Officer-in-charge—R. F. Turnbull, B.E.
Senior Research Officer—K. F. Plomley, B.Sc.Agr.
Research Officer—W. M. McKenzie, M.Sc.(For.).
Senior Technical Officer—R. L. Cowling, Dip.Mech. Eng., Dip.E.E.
Senior Technical Officer—D. S. Jones, B.C.E.
Technical Officer—M. W. Page.
Technical Officer—R. J. Profitt, A.R.M.T.C.

17. DIVISION OF INDUSTRIAL CHEMISTRY.

(Head-quarters: Lorimer-street, Fishermen's Bend, Victoria.)

Administration—

Chief—I. W. Wark, D.Sc., Ph.D., F.A.A.
Divisional Secretary—W. E. Ewers, M.Sc.
Assistant Secretary—J. P. Shelton, M.Sc., A.B.S.M.

Minerals Utilization Section—

Chief Research Officer—R. G. Thomas, B.Sc.
Principal Research Officer—F. K. McTaggart, M.Sc.
Principal Research Officer—I. E. Newnham, M.Sc. (Hons.).
Principal Research Officer—T. R. Scott—D.Sc., B.Ed.
Principal Research Officer—A. D. Wadsley, D.Sc.
Principal Research Officer—A. Walkley, B.A., D.Sc., Ph.D.
Principal Research Officer—A. W. Wylie, D.Sc., Ph.D.
Senior Research Officer—R. C. Croft, M.Sc.
Senior Research Officer—E. S. Pilkington, A.S.T.C.
Research Officer—K. J. Cathro, B.E., Ph.D.
Research Officer—D. F. A. Koch, M.Sc.
Research Officer—D. E. Scaife, B.Sc.(Hons.).
Research Officer—A. G. Turnbull, B.Chem.Eng., M.Eng.Sc. (on study leave).
Research Officer—I. H. Warren, B.Sc.(Hons.), Dipl.Chem.Techn.
Principal Technical Officer—H. R. Skewes, A.A.C.I.
Senior Technical Officer—Miss I. J. Bear, A.R.M.T.C.
Senior Technical Officer—Miss E. E. Rutherford, B.Sc.
Technical Officer—B. M. Beattie, B.Sc.
Technical Officer—L. J. Rogers, F.R.M.T.C.
Technical Officer—P. R. Smith, A.R.M.T.C.

Cement and Ceramics Section—

Principal Research Officer—A. J. Gaskin, M.Sc.
Principal Research Officer—H. E. Vivian, B.Sc.Agr.
Principal Research Officer—G. F. Walker, B.Sc., Ph.D.
Principal Research Officer—W. O. Williamson, B.Sc. (Hons.), Ph.D.
Senior Research Officer—K. M. Alexander, M.Sc., Ph.D.
Senior Research Officer—S. M. Brisbane, B.A., B.Sc., A.R.M.T.C.
Senior Research Officer—H. Ellerton (at Bonython Research Laboratory, School of Mines, Adelaide).
Senior Research Officer—L. S. Williams, D.Phil., B.E.
Research Officer—G. M. Bruère, M.Sc.
Research Officer—J. Graham, M.Sc., Ph.D.
Research Officer—J. H. Taplin, B.Sc. (Hons.)
Senior Technical Officer—C. E. S. Davis, B.Sc. (Hons.).
Senior Technical Officer—K. Grant, B.Sc. (Hons.).
Senior Technical Officer—R. R. Hughan.
Senior Technical Officer—J. H. Weymouth, B.Sc.
Senior Technical Officer—J. D. Wolfe.
Technical Officer—Miss V. Anderlini, D.Chem.
Technical Officer—F. J. Darragh, B.Sc. (Hons.).
Technical Officer—W. G. Garrett, A.R.M.T.C.
Technical Officer—F. C. Gillespie, B.Sc. (at Bonython Research Laboratory, School of Mines, Adelaide).
Technical Officer—Miss B. C. Terrell, B.Sc.
Technical Officer—J. Wardlaw, B.Sc.

Foundry Sands Section—

Senior Research Officer—H. A. Stephens, B.Sc. (Hons.).
Senior Technical Officer—A. N. Waterworth, A.H.T.C., A.R.M.T.C.
Technical Officer—P. W. Goad, F.R.M.T.C.

Chemical Physics Section—

Assistant Chief of Division—A. L. G. Rees, D.Sc., Ph.D., F.A.A.
Senior Principal Research Officer—A. Walsh, M.Sc. Tech.
Principal Research Officer—J. L. Farrant, M.Sc.
Principal Research Officer—A. McL. Mathieson, D.Sc., Ph.D.
Principal Research Officer—J. J. McNeill, M.Sc.
Principal Research Officer—D. A. Davies, B.Sc.
Principal Research Officer—J. M. Cowley, D.Sc., Ph.D.
Principal Research Officer—J. D. Morrison, B.Sc., Ph.D. (on leave).
Senior Research Officer—A. J. C. Nicholson, M.Sc., Ph.D.
Senior Research Officer—J. B. Willis, M.Sc., Ph.D.
Senior Research Officer—J. Fridrichsons, M.Sc.

Senior Research Officer—G. R. Hercus, M.Sc., D.Phil.
Senior Research Officer—B. Dawson, M.Sc., Ph.D.
Senior Research Officer—C. K. Coogan, M.Sc., Ph.D.
Senior Research Officer—A. F. Moodie, B.Sc. (Hons.).
Senior Research Officer—F. H. Dorman, M.A., M.Sc., Ph.D.
Senior Research Officer—R. N. Beale, B.Sc., Ph.D.
Research Officer—A. C. Hurley, M.A., B.Sc., Ph.D. (on leave).
Research Officer—C. Billington, B.A.
Research Officer—J. O. Cope, M.Sc., Ph.D.
Research Officer—A. F. Beecham, B.Sc. (Hons.).
Research Officer—J. D. McLean, B.Sc. (Hons.).
Research Officer—N. S. Ham, M.Sc., Ph.D.
Research Officer—J. C. Riviere, M.Sc., Ph.D.
Research Officer—J. V. Sullivan, M.Sc. (at University of Western Australia, Perth).
Research Officer—P. Goodman, M.Sc.
Research Officer—W. C. T. Dowell, M.Sc.
Research Officer—Miss Barbara J. Russell, M.Sc.
Senior Technical Officer—S. E. Powell.
Senior Technical Officer—G. F. H. Box.
Senior Technical Officer—E. Chakanovskis, Dipl.Eng.
Technical Officer—D. L. Swingler, B.Sc.
Draughtsman, Grade II.—B. G. Nicholson.

Physical Chemistry Section—

Assistant Chief of Division—K. L. Sutherland, D.Sc., Ph.D.
Principal Research Officer—V. A. Garten, D.Sc.
Principal Research Officer—S. D. Hamann, M.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).
Principal Research Officer—D. E. Weiss, B.Sc.
Principal Research Officer—M. E. Winfield, D.Sc., Ph.D.
Senior Research Officer—J. A. Barker, B.A. (Hons.), B.Sc.
Senior Research Officer—I. Brown, B.Sc. (Hons.).
Senior Research Officer—H. G. David, B.Sc., Dip.Ed. (at Department of Chemical Engineering, University of Sydney).
Senior Research Officer—W. N. K. King, B.Sc.
Senior Research Officer—W. W. Mansfield, B.Sc. (Hons.).
Senior Research Officer—E. A. Swinton, B.Sc. (Hons.)
Senior Research Officer—R. G. Vines, M.Sc., B.Sc. (Oxon.).
Research Officer—F. H. Barr-David, B.Sc.App. (Hons.), B.E. (Hons.), D.Eng.
Research Officer—A. H. Ewald, B.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).
Research Officer—R. B. Head, M.Sc., Ph.D.
Research Officer—A. R. King, B.Sc. (Hons.), Ph.D., D.I.C.
Principal Technical Officer—L. F. Evans, D.S.M.B.
Senior Technical Officer—R. McNeill, A.Sw.T.C.
Technical Officer—K. Eppinger, B.Sc.
Technical Officer—W. Fock, B.Sc.
Technical Officer—M. Linton, B.Sc.
Technical Officer—F. Smith, B.Sc.
Technical Officer—Miss J. H. Urbahns, B.Sc.

Organic Chemistry Section—

Senior Principal Research Officer—H. H. Hatt, D.Sc., Ph.D.
Senior Principal Research Officer—J. R. Price, D.Sc., D.Phil.
Principal Research Officer—K. E. Murray, B.Sc. (Hons.).
Principal Research Officer—W. Zimmerman, D.Ing.
Senior Research Officer—R. B. Bradbury, B.Agr.Sc., Ph.D.
Senior Research Officer—W. D. Crow, M.Sc., Ph.D.
Senior Research Officer—C. C. J. Culvenor, M.Sc., Ph.D., D.Phil.
Senior Research Officer—L. K. Dalton, A.S.T.C.
Senior Research Officer—J. S. Fitzgerald, M.Sc., Ph.D., D.I.C.
Senior Research Officer—N. C. Hancox, M.Sc.
Research Officer—C. S. Barnes, M.Sc., Ph.D.
Research Officer—A. L. J. Beckwith, B.Sc., D.Phil.
Research Officer—J. R. Cannon, M.Sc., Ph.D.
Research Officer—D. T. Downing, B.Sc. (Hons.), Ph.D.
Research Officer—E. Gellert, Ph.D.
Research Officer—J. A. Lamberton, B.Sc. (Hons.), Ph.D.
Research Officer—P. C. Wailes, M.Sc., Ph.D.
Senior Technical Officer—Z. Kranz, Ind.Chem.
Senior Technical Officer—P. M. Hunter, A.Sw.T.C.
Technical Officer—Miss N. H. Corbett, B.Sc.
Technical Officer—Mrs. F. O. Doy, B.Sc. (Hons.).
Technical Officer—A. H. Redcliffe, A.R.M.T.C.
Technical Officer—Mrs. I. Salivin, A.R.M.T.C.
Technical Officer—L. W. Smith, B.Sc.

Chemical Engineering Section—

Principal Research Officer—R. W. Urie, B.Sc., S.M.
Senior Research Officer—T. J. Birch, Dip.Chem.Eng.
Senior Research Officer—J. D. Blackwood, M.Sc., Ph.D.
Senior Research Officer—O. G. Ingles, B.A., M.Sc.
Senior Research Officer—A. B. Whitehead, B.Sc. (Hons.).
Research Officer—K. J. Cannon, B.E., Ph.D.
Research Officer—K. R. Hall, M.Sc.
Research Officer—P. Terry, B.Sc. (Hons.), M.S. (Chem.Eng.).
Principal Technical Officer—B. W. Wilson, M.Sc.
Senior Technical Officer—A. J. Stedman, M.A. (Cantab.).
Technical Officer—P. Casamento, D.Chem.
Technical Officer—J. D. Fock, Dip.Chem.
Technical Officer—C. J. Restarick, A.S.M.B.

Engineering Services—

Principal Technical Officer—J. B. Ross, B.Sc., A.R.M.T.C.
Sectional Draughtsman—C. Simpson.

Library—

Librarian—Miss B. M. Brown, B.Sc.
Librarian—Mrs. D. E. Lamberton, B.A.

18. INDUSTRIAL RESEARCH LIAISON SECTION.

(Head-quarters: 314 Albert-street, East Melbourne, Victoria.)

Officer-in-charge—L. Lewis, B.Met.E.
Senior Research Officer—J. F. H. Wright, B.Sc.
Senior Technical Officer—J. D. Dover, A.S.T.C.

19. IRRIGATION RESEARCH STATIONS.

(Head-quarters: Merbein, Victoria.)

Senior Officer-in-charge—F. Penman, M.Sc.

At Commonwealth Research Station, Merbein (Murray Irrigation Areas)—

Officer-in-charge—F. Penman, M.Sc.
Technical Secretary—D. V. Walters, M.Agr.Sc.
Principal Research Officer—J. G. Baldwin, B.Agr.Sc., B.Sc.
Research Officer—W. J. Webster, B.Sc.
Research Officer—A. J. Antcliff, B.Sc. (Hons.).
Research Officer—M. R. Sauer, B.Agr.Sc.
Research Officer—S. F. Bridley, B.Agr.Sc.
Research Officer—R. C. Woodham, B.Agr.Sc.

Research Officer—D. McE. Alexander, B.Sc.
Research Officer—A. F. Bird, M.Sc., Ph.D.
Research Officer—J. V. Seekamp, B.Agr.Sc. (part-time).
Senior Technical Officer—J. E. Giles.
Technical Officer—S. A. Giddings, B.Sc. (on leave abroad).
Technical Officer—P. May, Ing.Agr.
Technical Officer—D. G. M. Blair, B.Agr.Sc.
Librarian—Miss E. A. Stone, B.A. (Hons.).

At Irrigation Research Station, Griffith (Murrumbidgee Irrigation Areas)—
Acting Officer-in-charge—E. Levi, M.Sc.
Senior Research Officer—C. T. Gates, M.Sc.Agr.
Research Officer—R. F. Black, B.Sc. (Hons.).
Research Officer—T. Talsma, Ing.Agr.
Research Officer—D. Bouma, Ing.Agr.
Research Officer—H. Groenewegen, Ing.Agr.
Research Officer—Miss J. Connor, B.Sc., Ph.D.
Librarian—Miss M. Russell.

20. DIVISION OF LAND RESEARCH AND REGIONAL SURVEY.

(Head-quarters: Canberra, Australian Capital Territory.)

Head-quarters—
Chief—C. S. Christian, B.Agr.Sc., M.S.
Technical Secretary—Miss M. C. Mills, B.Sc. (Hons.).
Technical Officer—W. J. Curnow, B.Sc.

Regional Surveys—
Principal Research Officer—G. A. Stewart, M.Agr.Sc.

Australian Mainland Survey, Canberra—
Senior Research Officer—N. H. Speck, M.Sc., B.A.
Research Officer—W. H. Litchfield, B.Sc.Agr. (seconded from Division of Soils).
Research Officer—J. J. Basinski, B.Sc., M.A.
Technical Officer—M. Lazarides, Q.D.A.

Papua-New Guinea Survey, Canberra—
Senior Research Officer—H. A. Haantjens, Ing.Agr.
Senior Research Officer—R. D. Hoogland, D.Sc.
Research Officer—E. J. Reiner, Dr.rer.nat.
Research Officer—G. R. Robbins, B.Sc., M.Sc.
Technical Officer—J. C. Saunders, B.Sc.Agr.

Agricultural Research—
Principal Research Officer—E. Phillis, Ph.D., D.Sc.

At Katherine Research Station, Northern Territory—
Research Officer—W. Arndt, B.Agr.Sc.
Research Officer—M. J. T. Norman, B.Sc. (Hons.), Ph.D.
Research Officer—R. Wetselaar, Ing.Agr.
Technical Officer—L. J. Phillips, Q.D.D.M.
Technical Officer—W. R. Stern, M.Sc.Agr. (on leave).

At Kimberley Research Station, Western Australia—
Technical Officer—E. C. B. Langfield.
Technical Officer—A. L. Chapman, B.Agr.Sc.

Climatology, Canberra—
Research Officer—R. O. Slatyer, M.Sc.(Agric.).
Research Officer—J. L. Frith, B.Sc.(Agric.) (Hons.).
Research Officer—J. C. Turner, B.Sc.Agr. (Hons.).

Geomorphology, Canberra—
Senior Research Officer—J. A. Mabbutt, M.A. (Hons.).

Arid Zone Research—
Senior Research Officer—R. A. Perry, M.Sc.

At Alice Springs—
Technical Officer—R. E. Winkworth, B.Sc. (Hons.).

21. MATHEMATICAL INSTRUMENTS SECTION.

(Head-quarters: Department of Electrical Engineering, University of Sydney.)

Officer-in-charge—Professor D. M. Myers, B.Sc., D.Sc.Eng.
Research Officer—M. W. Allen, B.E. (Hons.).

22. DIVISION OF MATHEMATICAL STATISTICS.

(Head-quarters: University of Adelaide.)

At Head-quarters, Adelaide—
Chief—E. A. Cornish, B.Agr.Sc., D.Sc., F.A.A.
Principal Research Officer—A. T. James, M.Sc., Ph.D.
Research Officer—G. N. Wilkinson, B.Sc. (Hons.).
Research Officer—A. G. Constantine, B.Sc. (Hons.).
Technical Officer—Miss M. J. Evans, B.A.

At Division of Animal Health and Production, Prospect, New South Wales—
Research Officer—H. Weiler, Lic.ès.Sc. (Par.), M.Sc.

At Division of Animal Health and Production, Sydney—
Research Officer—A. M. W. Verhagen, Cand.Nat. Phil. (Utrecht), B.A. (Hons.).

At Division of Building Research, Highett, Victoria—
Senior Research Officer—R. Birtwistle, B.Sc.
Research Officer—G. A. Watterson, B.A. (Hons.).

At Division of Food Preservation and Transport, Homebush, New South Wales—
Senior Research Officer—G. G. Coote, B.A., B.Sc.
Research Officer—A. G. L. Elliott, B.Sc. (Hons.).

At Division of Forest Products, Melbourne—
Principal Research Officer—E. J. Williams, B.Com., D.Sc. (on leave of absence).
Research Officer—W. R. Flower, B.Sc., B.A. (Hons.).
Technical Officer—Miss N. Ditchburne.

At Division of Plant Industry, Brisbane—
Research Officer—K. P. Haydock, B.Sc. (Hons.).

At Division of Plant Industry, Canberra—
Senior Principal Research Officer—G. A. McIntyre, B.Sc. (Hons.), Dip.Ed.
Research Officer—M. L. Dudzinski, B.Sc., B.Ec. (Hons.).

At Regional Pastoral Laboratory, Armidale, New South Wales—
Research Officer—P. F. May, B.Agr.Sc. (Hons.).

At University of Melbourne—
Research Officer—G. W. Hill, M.Sc.

At Western Australian Regional Laboratory, Perth—
Senior Research Officer—N. S. Stenhouse, B.Sc.

At Wool Textile Research Laboratory, Melbourne—
Research Officer—W. B. Hall, B.A.

23. DIVISION OF METEOROLOGICAL PHYSICS.

(Head-quarters: Station-street, Aspendale, Victoria.)

Chief—C. H. B. Priestley, M.A., Sc.D., F.A.A.
Senior Principal Research Officer—W. C. Swinbank, B.Sc. (Hons.).
Principal Research Officer—E. L. Deacon, B.Sc.
Principal Research Officer—A. F. A. Berson, Dr.Phil.
Senior Research Officer—R. J. Taylor, B.Sc.
Senior Research Officer—I. C. McIlroy, B.Sc.
Senior Research Officer—E. K. Webb, B.A. (Hons.), B.Sc.
Senior Research Officer—R. H. Clarke, B.A., B.Sc.
Research Officer—A. J. Dyer, M.Sc., Ph.D.
Research Officer—F. K. Ball, B.Sc. (Hons.).
Research Officer—C. F. Barrett, M.Sc.
Research Officer—P. J. Funk, Dr.Phil.
Senior Technical Officer—D. E. Angus, B.Sc.
Senior Technical Officer—R. R. McGregor, A.R.M.T.C.
Technical Officer—A. J. Troup, B.Sc.
Technical Officer—D. R. Samuel, A.R.M.T.C.
Technical Officer—N. E. Bacon, B.Sc.
Technical Officer—Miss S. A. Yeo, B.Sc.
Sectional Draughtsman—C. J. Sumner.

24. Division of Metrology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Administration—

Chief—N. A. Esserman, B.Sc.

Length Section—

Principal Research Officer—M. J. Puttock, B.Sc. (Eng.).
Senior Research Officer—N. J. C. Peres, M.Sc.
Research Officer—Miss M. G. I. Pearce, M.Sc.
Research Officer—E. G. Thwaite, B.Sc.
Research Officer—P. J. Sim, B.E., B.Sc.
Principal Technical Officer—R. H. Furniss, A.S.T.C.
Senior Technical Officer—B. H. P. Cresswell, A.S.T.C.
Senior Technical Officer—Miss M. C. Dive, B.Sc.
Technical Officer—W. A. F. Cuninghame, B.E.
Technical Officer—Miss P. M. Yelland.
Technical Officer—J. W. Bell.

Mass Section—

Principal Research Officer—G. A. Bell, B.Sc.
Research Officer—I. F. Mayer, B.E., B.Sc.
Senior Technical Officer—J. W. Humphries, B.Sc.
Senior Technical Officer—Misss M. M. Douglas, B.Sc.
Technical Officer—E. Grunwald, Dip.Ing.

Interferometry Section—

Principal Research Officer—C. F. Bruce, M.Sc.
Senior Research Officer—H. J. Ritter, Dr.rer.nat. math.
Research Officer—P. E. Ciddor, M.Sc.
Technical Officer—R. S. Fisher, A.R.M.T.C.
Technical Officer—S. T. Willatt, B.Sc. (Hons.).

Electronics Section—

Senior Research Officer—H. A. M. Ross, A.S.T.C.

Applied Mechanics Section—

Senior Principal Research Officer—C. A. Gladman, B.Sc. (Eng.).
Principal Research Officer—J. A. Macinante, B.E.
Senior Research Officer—G. Lorenz, M.E.
Principal Technical Officer—R. S. Springer, Dr.Ec., Dr.Eng.
Senior Technical Officer—R. J. Ellis, B.E.
Senior Technical Officer—J. Waldersee, B.Sc.
Senior Technical Officer—D. H. Fox.
Senior Technical Officer—A. A. V. Gibson, A.S.T.C.
Technical Officer—L. Cridland, B.E.
Technical Officer—K. H. Edensor, A.S.T.C.

25. Mineragraphic Investigations.

(Head-quarters: University of Melbourne.)

Officer-in-charge—A. B. Edwards, D.Sc., Ph.D., D.I.C.
Senior Research Officer—G. Baker, D.Sc.
Senior Research Officer—J. McAndrew, M.Sc., Ph.D.
Research Officer—I. M. Threadgold, B.Sc.
Research Officer—K. L. Williams, B.Sc. (Hons.).
Technical Officer—A. W. Hounslow, F.R.M.T.C.

26. National Standards Laboratory.

(The services shown hereunder are common to the Divisions of Metrology, Electrotechnology, and Physics, housed in the Laboratory at the University of Sydney.)

Clerical—

Chief Clerk—W. J. Gillespie, F.A.S.A., A.C.I.S., J.P.
Accountant—F. J. Whitty.

Library—

Senior Librarian—Miss M. McKechnie, B.A.
Librarian—Miss J. M. Cook, B.A. (Hons.).
Librarian—Miss P. M. Callaghan, B.Sc.
Librarian—Mrs. M. P. Fowler, B.Sc.
Librarian—Miss P. I. Ross, B.A.
Librarian—Mrs. J. M. Chambers, B.A.

Workshops—

Principal Technical Officer—J. Hanna.

Drawing Office—

Chief Draughtsman—J. Coles.
Sectional Draughtsman—I. A. Rey, A.M.I.E., I.E.E. (Eng.).
Sectional Draughtsman—R. A. Partridge.
Draughtsman, Grade II.—J. R. B. Weir.
Draughtsman, Grade II.—E. Zala, B.Mech.Eng. (Brunn).
Draughtsman, Grade II.—T. H. Gruetzmacher.
Draughtsman, Grade II.—E. Emanuel.
Draughtsman, Grade II.—R. J. Taylor.

27. Ore-dressing Investigations.

(Head-quarters: University of Melbourne.)

Officer-in-charge—Associate Professor H. H. Dunkin, B.Met.E.
Principal Research Officer—K. S. Blaskett, B.E.
Research Officer—S. B. Hudson, M.Sc.
Research Officer—J. T. Woodcock, B.Met.E., M.Eng.Sc.
Senior Technical Officer—F. D. Drews.
Technical Officer—W. J. Trahar, B.Sc.

28. Physical Metallurgy Section.

(Head-quarters: University of Melbourne.)

Officer-in-charge—Professor H. W. Worner, D.Sc.
Senior Research Officer—R. C. Gifkins, B.Sc.
Research Officer—D. R. Miller, M.Sc.
Research Officer—J. W. Suiter, M.Sc., Ph.D. (on leave overseas).
Senior Technical Officer—J. A. Corbett.
Technical Officer—H. F. Ryan, B.Sc.

29. Division of Physics.

(Head-quarters: National Standards Laboratory at the University of Sydney.)

Administration—

Chief—G. H. Briggs, D.Sc., Ph.D.
Laboratory Secretary—A. G. Driver, B.Sc.

Heat—

Principal Research Officer—A. F. A. Harper, M.Sc.
Senior Research Officer—W. R. G. Kemp, B.Sc.
Senior Research Officer—R. G. Wylie, M.Sc., Ph.D.
Senior Research Officer—P. G. Klemens, M.Sc., D.Phil.
Senior Research Officer—G. S. Bogle, M.A., D.Phil. (Oxon.), M.Sc.(N.Z.).
Research Officer—W. A. Caw, B.Sc. (Hons.).
Research Officer—J. Middlehurst, M.Sc.
Research Officer—J. V. McAllan, B.Sc. (Hons.).
Senior Technical Officer—Miss I. M. Beavis, B.Sc., Dip. Ed.
Technical Officer—T. P. Jones, B.Sc.
Technical Officer—R. P. McDonald, M.Sc.
Technical Officer—Mrs. W. Szulmayer, Dipl.Phys.
Technical Officer—R. J. Tainsh, A.S.T.C.
Technical Officer—N. R. Hickson, B.Sc.

Light—

Senior Principal Research Officer—R. G. Giovanelli, D.Sc.
Senior Research Officer—W. H. Steel, B.A. (Hons.), B.Sc., Dr.ès.Sc.
Research Officer—W. R. Blevin, M.Sc., Dip.Ed.
Research Officer—C. E. Coulman, M.Sc., D.I.C.
Senior Technical Officer—K. A. B. Wright, B.Sc.
Technical Officer—W. J. Brown, A.S.T.C.
Technical Officer—Miss M. C. Cunningham, B.Sc. (Hons.).

Solar Physics—
Senior Research Officer—J. T. Jefferies, M.A., B.Sc. (Hons.) (abroad).
Research Officer—R. E. Loughhead, M.Sc.
Research Officer—R. J. Bray, M.A. (Oxon.), D.Phil.
Technical Officer—V. R. Burgess, A.S.T.C.
Technical Officer—Miss M. K. McCabe, M.Sc.

Electronics—
Research Officer—A. F. Young, M.Sc.
Technical Officer—P. F. Howden, B.Sc.

30. Plant Fibre Section.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-charge—W. L. Greenhill, M.E.

Fodder Conservation—
Senior Research Officer—G. W. Lanigan, M.Sc.
Senior Research Officer—Miss J. F. Couchman, M.Sc.
Research Officer—W. Shepherd, B.Sc., B.Agr.Sc.
Senior Technical Officer—J. de Freitas, F.R.M.T.C.
Technical Officer—C. J. Brady, B.Sc.Agr.
Technical Officer—R. E. Spielrein, A.R.M.T.C.

Agricultural Engineering—
Senior Research Officer—J. H. McClelland, B.Sc., M.Agr.Sc.
Technical Officer—R. C. R. Johnston, B.Mech.E., M.Eng.Sc.
Draughtsman, Grade II.—M. J. Taylor.

31. Division of Plant Industry.

(Head-quarters: Canberra, Australian Capital Territory.)

Administration—
Chief—O. H. Frankel, D.Sc., D.Agr., F.A.A., F.R.S.
Associate Chief—J. Griffiths Davies, B.Sc., Ph.D.
Assistant Chief—R. M. Moore, M.Sc.Agr.
Technical Secretary—A. Shavitsky, B.Agr.Sc. (seconded to London).
Acting Technical Secretary—J. H. E. Mackay, B.Sc.Agr.
Assistant Technical Secretary—L. G. Wilson, M.Sc.
Divisional Engineer—G. L. Brown, B.Sc.(Eng.).
Draughtsman, Grade II.—G. J. Row.

At Canberra, Australian Capital Territory—
Genetics, Cytology, and Structural Botany—
Chief of the Division—O. H. Frankel, D.Sc., D.Agr., F.A.A., F.R.S.
Principal Research Officer—C. Barnard, D.Sc.
Principal Research Officer—J. B. Griffing, M.S., Ph.D.
Principal Research Officer—F. H. W. Morley, B.V.Sc., Ph.D.
Senior Research Officer—R. D. Brock, M.Agr.Sc., Ph.D.
Research Officer—H. Daday, M.Sc.
Research Officer—C. I. Davern, M.Sc.Agr. (overseas).
Research Officer—D. L. Hayman, B.Ag.Sc. (Hons.).
Research Officer—J. B. Langridge, M.Sc., Ph.D.
Research Officer—R. N. Oram, B.Ag.Sc. (Hons.).
Research Officer—D. C. Wark, M.Agr.Sc.
Technical Officer—J. A. M. Brown, B.Sc.Agr.
Technical Officer—Miss A. M. Munday, B.Sc.
Technical Officer—J. W. Peak.

Herbarium—
Senior Research Officer—Miss N. T. Burbidge, M.Sc.

Plant Introduction—
Senior Principal Research Officer—W. Hartley, B.A., Dip.Ag.
Senior Research Officer—C. A. Neal-Smith, B.Ag.Sc.
Senior Technical Officer—Miss D. E. Johns, B.Sc.
Technical Officer—R. J. Williams, M.Sc.

Microbiology—
Senior Research Fellow—K. O. Müller, D.Phil.
Senior Research Officer—F. W. Hely, M.Sc.Agr., M.S.
Research Officer—F. J. Bergersen, M.Sc. (Hons.).
Research Officer—I. A. M. Cruickshank, M.Sc. (Hons.).
Research Officer—A. H. Gibson, B.Sc.Agr. (Hons.) (overseas).
Research Officer—Miss K. Helms, M.Sc., Ph.D.
Research Officer—M. Zaitlin, B.S., Ph.D.
Technical Officer—J. Brockwell, D.D.A.
Technical Officer—Mrs. S. M. R. Jerome, B.Sc. (Hons.).

Disease Control—
Principal Research Officer—H. R. Angell, O.B.E., B.Sc.Agr., M.S., Ph.D.

Tobacco Investigations—
Principal Research Officer—A. V. Hill, M.Agr.Sc.
Technical Officer—M. Mandryk, B.Sc.Agr.

General Chemistry—
Principal Research Officer—C. H. Williams, M.Sc.
Senior Research Officer—D. J. Cosgrove, B.Sc. (Hons.), Ph.D.
Senior Research Officer—A. Steinbergs, Dip.Chem. Eng. (Riga).
Research Officer—D. J. David, M.Sc.
Technical Officer—J. R. Twine, Dip.Ind.Chem.

Plant Nutrition—
Senior Principal Research Officer—A. J. Anderson, D.Sc.(Agric.).
Senior Research Officer—K. D. McLachlan, B.Sc. Agr., B.Com.
Senior Research Officer—D. Spencer, B.Sc. (Hons.), Ph.D.
Research Officer—J. F. Loneragan, B.Sc. (Hons.), Ph.D.
Research Officer—J. V. Possingham, B.Ag.Sc. (Hons.), Ph.D. (overseas).

Plant Biochemistry and Biophysics—
Senior Principal Research Officer—J. E. Falk, M.Sc., Ph.D.
Principal Research Officer—C. G. Greenham, M.Sc.
Senior Research Officer—N. K. Boardman, M.Sc., Ph.D.
Senior Research Officer—W. Bottomley, B.Sc. (Hons.), Ph.D.
Senior Research Officer—P. L. Goldacre, M.Sc., Ph.D.
Senior Research Officer—J. N. Phillips, M.Sc., Ph.D.
Research Officer—C. A. Appleby, B.Sc. (Hons.).
Research Officer—S. M. Bromfield, M.Agr.Sc., Ph.D.
Research Officer—P. A. Trudinger, B.Sc. (Hons.), Ph.D.
Research Officer—N. A. Walker, B.Sc. (Hons.).
Research Officer—P. R. Whitfeld, B.Sc. (Hons.), Ph.D.
Senior Technical Officer—P. I. Mortimer, M.Sc.
Technical Officer—P. K. Macnicol, B.Sc.

Plant Physiology—
Principal Research Officer—L. A. T. Ballard, M.A., M.Agr.Sc., Ph.D.
Principal Research Officer—R. F. Williams, D.Sc.
Senior Research Officer—A. H. G. C. Rijven, B.Sc., Ph.D.
Research Officer—L. T. Evans, B.Sc., M.Agr.Sc., D.Phil.
Research Officer—N. P. Kefford, M.Sc., Ph.D.
Research Officer—W. G. Slater, M.Sc., D.Phil.
Research Officer—J. A. Zwar, M.Ag.Sc.
Technical Officer—Miss E. A. Grant-Lipp, M.Sc.

Ecology—
Assistant Chief of the Division—R. M. Moore, M.Sc.Agr.
Senior Research Officer—E. F. Biddiscombe, M.Sc. (Agric.).
Senior Research Officer—R. W. Jessup, M.Sc.
Senior Research Officer—C. W. E. Moore, M.Agr.Sc.
Senior Research Officer.—G. Scurfield, B.Sc., Dip.Ed., Ph.D.
Technical Officer—J. A. Robertson, Q.D.D.M.
Alpine Ecology—
Senior Research Officer—A. B. Costin, B.Sc.Agr. (Hons.).
Technical Officer—D. J. Wimbush, B.Sc.
Agronomy—
Senior Research Officer—W. D. Andrew, M.Agr.Sc.
Senior Research Officer—W. M. Willoughby, B.Sc.Agr.
Research Officer—H. L. Davies, B.Sc.(Agr.) (Hons.).
Research Officer—R. S. J. Lipsett, B.Agr.Sc. (Hons.).
Senior Technical Officer—W. Straatmans, Dip.Ag., Dip.Trop.Agr.
Technical Officer—J. D. Williams, D.D.A.
Dickson Experiment Station—
Senior Technical Officer—R. J. Hutchings, D.D.A.
At Plant and Soils Laboratory, Brisbane, Queensland—
Associate Chief—J. Griffiths Davies, B.Sc., Ph.D.
Laboratory Secretary—A. G. A. Eyles, B.Sc. (Agric.).
Agrostology—
Principal Research Officer—T. B. Paltridge, B.Sc. (Hons.).
(Seconded to Coconut Research Institute—Ceylon.)
Pasture Ecology—
Principal Research Officer—W. W. Bryan, M.Agr.Sc.
Senior Research Officer—N. A. Shaw, B.Agr.Sc. (Hons.).
Research Officer—O. T. Denmead, B.Agr.Sc. (Hons.).
Research Officer—L. A. Edye, B.Agr.Sc. (Hons.).
Research Officer—F. K. van der Kley, Ing.Agr.
Technical Officer—T. W. Elich, Dip.Col.Agr.
Plant Nutrition and Physiology—
Senior Research Officer—C. S. Andrew, B.Agr.Sc., B.Sc. (Hons.).
Research Officer.—R. G. Coleman, B.Sc.(Agric.), Ph.D., D.I.C.
Research Officer—E. F. Henzell, B.Agr.Sc. (Hons.), D.Phil.
Technical Officer—W. H. J. Pieters, Dip.Col.Agr.
Plant Chemistry—
Research Officer—M. P. Hegarty, M.Sc., Ph.D.
Technical Officer—Miss P. M. Thorne, B.Sc.
Ecology—
Senior Research Officer—J. E. Coaldrake, M.Sc.
Technical Officer—W. F. Ridley, B.Sc.
Genetics—
Senior Principal Research Officer—E. M. Hutton, B.Ag.Sc., D.Sc.
Research Officer—J. J. Yates, B.Sc. (Agric.) (Hons.).
Legume Bacteriology—
Principal Research Officer—D. O. Norris, D.Sc. (Agric.)
Plant Introduction—
Principal Research Officer—J. F. Miles, M.Agr.Sc.
Research Officer—E. H. Kipps, B.Sc.
At Cooper Laboratory, Lawes, Queensland—
Senior Technical Officer—R. Milford, B.Agr.Sc.
Technical Officer—H. Kiers, Dip.Col.Agr.
At Regional Pastoral Laboratory, Armidale, New South Wales—
Pasture Investigations—
Principal Research Officer—R. Roe, B.Sc. (Agric.).
Senior Research Officer—E. J. Hilder, B.Sc. (Agric.).
Senior Research Officer—K. Spencer, B.Sc.Agr. (Hons.), M.S.
Research Officer—J. E. Begg, B.Sc.Agr. (Hons.).
Technical Officer—N. J. Barrow, M.Agr.Sc.
Technical Officer—J. R. Freney, M.Sc.
Technical Officer—B. E. Mottershead, B.Sc.
Technical Officer—J. A. Thompson, B.Sc. (For.).
Technical Officer—V. J. Wolfe, Q.D.A.

At Regional Pastoral Laboratory, Deniliquin, New South Wales—
Officer-in-charge—L. F. Myers, M.Agr.Sc.
Pasture Investigations—
Research Officer—J. L. Davidson, M.Ag.Sc.
Research Officer—O. B. Williams, M.Agr.Sc.
Technical Officer—R. J. Hunter, B.Sc.
Technical Officer—C. R. Kleinig, B.Ag.Sc. (Hons.).
Technical Officer—Miss V. E. Rogers, B.A. (Hons.).
Agricultural Physics—
Principal Research Officer—D. A. deVries, D.Sc.
Senior Research Officer—J. R. Philip, B.C.E.
Technical Officer—A. J. Peck, B.Sc. (Hons.).

At Regional Laboratory, Perth, Western Australia—
Pasture Investigations—
Principal Research Officer—R. C. Rossiter, D.Sc. (Agric.).
Research Officer—A. W. Humphries, B.Sc.Agric. (Hons.).
Research Officer—P. G. Ozanne, B.Sc. (Agric.).
Senior Technical Officer—T. C. Shaw, B.Sc.
Technical Officer—D. J. Kirton, B.Sc. (Agric.).
Technical Officer—R. J. Pack, Q.D.A.
Plant Introduction—
Senior Research Officer—E. T. Bailey, B.Sc. (Hons.).

At "Glen Lossie" Field Station, Kojonup, Western Australia—
Senior Research Officer—E. R. Watson, M.Sc. (Agric.).
Technical Officer—P. Lapins, Dip.Agronom. (Riga).

At Tasmanian Regional Laboratory, Hobart—
Fruit Investigations—
Principal Research Officer—D. Martin, D.Sc.
Research Officer—T. L. Lewis, M.Sc.
Technical Officer—J. Cerny, Dr.Tech.Sc.

At Applethorpe, Queensland—
Fruit Investigations—
Principal Research Officer—L. A. Thomas, M.Sc.

At the University of Melbourne—
Soil Chemistry—
Senior Research Officer—L. H. P. Jones, B.Agr.Sc., Ph.D. (abroad).
Technical Officer—A. F. Sherrington, A.Sw.T.C.

At University of Queensland, Brisbane—
Ecology—
Senior Research Officer—L. J. Webb, M.Sc., Ph.D.

At Irrigation Research Station, Griffith, New South Wales—
Weed Ecology—
Research Officer—E. Levi, M.Sc.

At Tobacco Research Institute, Mareeba, Queensland—
Director—D. W. Goodall, Ph.D., D.Sc.
Research Officer—W. J. Lovett, B.Agr.Sc.
Research Officer—J. van der Harts, Ing.Agr.
Research Officer—P. J. Goodman, B.Sc., Ph.D.

32. DIVISION OF RADIOPHYSICS.

(Head-quarters: University Grounds, Sydney.)

Chief—E. G. Bowen, O.B.E., M.Sc., Ph.D., D.Sc., F.A.A.
Assistant Chief—J. L. Pawsey, M.Sc., Ph.D., F.A.A., F.R.S.
Technical Secretary—A. J. Higgs, B.Sc. (Hons.).
Principal Research Officer—L. L. McCready, B.Sc., B.E.

Cloud and Rain Physics—

Principal Research Officer—J. Warner, B.Sc., B.E.
Principal Research Officer—P. Squires, M.A.
Principal Research Officer—E. J. Smith, M.B.E., B.Sc. (Hons.).
Senior Research Officer—G. A. Day.
Senior Research Officer—E. K. Bigg, M.Sc., Ph.D.
Research Officer—N. R. Labrum, B.Sc. (Hons.).
Research Officer—A. A. Weiss, B.Sc. (Hons.), Ph.D.
Research Officer—E. E. Adderley, B.Sc.
Research Officer—S. Twomey, M.Sc., Ph.D.
Research Officer—J. M. Telford, B.Sc.
Research Officer—J. A. Warburton, B.Sc. (Hons.).
Senior Technical Officer—K. J. Heffernan.
Technical Officer—J. W. Smith, B.Sc. (Hons.).

Radio Astronomy—

Senior Research Fellow—R. Q. Twiss, M.A. (Cantab.), Sc.D.
Senior Principal Research Officer—J. H. Piddington, M.Sc., B.E., Ph.D.
Principal Research Officer—B. Y. Mills, B.Sc., M.E.
Principal Research Officer—W. N. Christiansen, D.Sc.
Principal Research Officer—J. P. Wild, M.A.
Senior Research Officer—C. A. Shain, B.Sc.
Senior Research Officer—S. F. Smerd, B.Sc. (Hons.).
Senior Research Officer—J. A. Roberts, M.Sc., Ph.D.
Research Officer—R. X. McGee, B.Sc. (Hons.).
Research Officer—E. R. Hill, M.Sc.
Research Officer—A. G. Little, B.Sc. (Hons.).
Research Officer—C. S. Gum, M.Sc., Ph.D.
Research Officer—A. W. L. Carter, B.Sc. (Hons.).
Research Officer—R. F. Mullaly, M.Sc., Ph.D.
Research Officer—B. R. Goddard, B.Sc., B.E.
Research Officer—D. S. Mathewson, M.Sc.
Senior Technical Officer—K. V. Sheridan, B.Sc., B.A.
Senior Technical Officer—K. R. McAlister, A.S.T.C.
Senior Technical Officer—J. V. Hindman.
Senior Technical Officer—J. D. Murray, B.Sc. (Eng.).
Senior Technical Officer—O. B. Slee, A.S.T.C.
Technical Officer—M. M. Komesaroff, B.Sc.

Radio Navigation and Propagation—

Principal Research Officer—M. Beard, B.Sc., B.E.
Research Officer—D. E. Yabsley, B.Sc., B.E.
Research Officer—F. F. Gardner, B.Sc., B.E., Ph.D.
Technical Officer—G. A. Chandler, A.S.T.C.

Semi-conductors and Transistors—

Principal Research Officer—B. F. C. Cooper, B.Sc. (Hons.), B.E.
Senior Research Officer—L. W. Davies, B.Sc. (Hons.), D.Phil.
Research Officer—R. D. Ryan, B.Sc. (Hons.), B.E.
Research Officer—N. H. Fletcher, B.Sc., M.A., Ph.D.
Research Officer—W. D. Edwards, B.Sc., Ph.D.
Senior Technical Officer—F. C. Tonking, A.S.T.C.
Technical Officer—B. M. Bartlett, B.Sc.

Test and Development—

Principal Technical Officer—G. A. Wells, A.S.T.C.
Senior Technical Officer—P. T. Hedges, A.S.T.C.
Technical Officer—T. E. Cousins, A.S.T.C.
Technical Officer—K. G. Weir, A.S.T.C.

Engineering Services—

Chief Draughtsman—F. M. Carter.
Draughtsman, Grade II.—H. F. Peddie, A.S.T.C.
Draughtsman, Grade II.—J. R. Morris.
Draughtsman, Grade II.—R. S. Fieldgate.
Draughtsman, Grade II.—R. Kenna, A.S.T.C.

Officers Abroad—

Principal Research Officer—H. C. Minnett, B.Sc., B.E.
Principal Research Officer—T. Pearcey, B.Sc. (Hons.).
Senior Research Officer—F. J. Kerr, M.Sc., M.A.
Senior Research Officer—R. N. Bracewell, B.Sc., M.E., Ph.D.
Research Officer—J. S. Turner, M.Sc., Ph.D.
Senior Technical Officer—G. J. Stanley, A.S.T.C.

33. Radio Research Laboratories.

(Head-quarters: Harben Vale, Camden, New South Wales.)

Chief Research Officer—D. F. Martyn, D.Sc., Ph.D., A.R.C.S., F.A.A., F.R.S.
Senior Principal Research Officer—G. H. Munro, D.Sc.
Senior Research Officer—W. L. Price, B.Sc. (part-time).
Research Officer—J. A. Harvey, M.Sc.
Research Officer—R. A. Duncan, B.Sc. (Hons.).
Senior Technical Officer—L. H. Heisler, B.Sc.
Technical Officer—R. B. White, B.E.

34. Division of Soils.

(Head-quarters: Waite Agricultural Research Institute, Adelaide.)

At Adelaide—

Administration—

Chief—J. K. Taylor, B.A., M.Sc., B.Sc.Agr.
Senior Clerical Officer—F. W. Blanksby.

Soil Survey and Pedology Section—

Senior Principal Research Officer—C. G. Stephens, D.Sc.
Senior Research Officer—K. H. Northcote, B.Agr.Sc.
Senior Research Officer—G. Blackburn, B.Agr.Sc.
Research Officer—E. A. Jackson, B.Ag.Sc.
Research Officer—C. B. Wells, B.Ag.Sc.
Research Officer—C. J. de Mooy, Ing.Agr.
Sectional Draughtsman—P. D. Hooper.

Soil Chemistry Section—

Senior Principal Research Officer—C. S. Piper, D.Sc.
Principal Research Officer—A. C. Oertel, M.Sc.
Senior Research Officer—J. T. Hutton, B.Sc., A.S.A.S.M.
Senior Research Officer—H. C. T. Stace, M.Sc.
Senior Research Officer—B. M. Tucker, B.A., B.Sc. (Hons.).
Research Officer—M. Raupach, M.Sc.
Technical Officer—K. G. Tiller, M.Sc.
Technical Officer—M. P. C. de Vries, Ing.Agr.
Technical Officer—A. R. P. Clarke, A.S.A.S.M.
Technical Officer—R. M. McKenzie, A.S.A.S.M.
Technical Officer—R. D. Bond, A.S.A.S.M.
Technical Officer—J B. Giles, B.Sc.

Soil Physics Section—

Senior Principal Research Officer—T. J. Marshall, M.Ag.Sc., Ph.D.
Senior Research Officer—J. W. Holmes, M.Sc.
Senior Research Officer—W. W. Emerson, B.A. (Oxon.), Ph.D.
Research Officer—E. L. Greacen, B.Sc.Agr. (Hons.), Ph.D.
Research Officer—C. G. Gurr, B.Sc.

Soil Microbiology Section—

Senior Principal Research Officer—R. J. Swaby, M.Sc., M.Agr.Sc., Ph.D.
Research Officer—J. R. Harris, M.Sc.
Research Officer—J. N. Ladd, M.Sc. (on study leave).
Research Officer—A. D. Rovira, B.Agr.Sc., Ph.D.
Technical Officer—Miss J. I. Sperber, B.Sc.

Soil Mechanics Section—

Principal Research Officer—G. D. Aitchison, M.E., Ph.D. (at University of Melbourne).
Technical Officer—I. B. Donald, B.C.E. (at University of Melbourne).

Clay Mineralogy Section—

Senior Research Officer—K. Norrish, M.Sc., Ph.D.
Research Officer—E. W. Radoslovich, M.Sc., Ph.D.
Technical Officer—R. M. Taylor, B.Sc.

At Brisbane—

Soil Survey and Pedology Section—

Principal Research Officer—G. D. Hubble, B.Ag.Sc.
Research Officer—G. G. Beckmann, B.Sc.
Research Officer—W. H. Litchfield, B.Sc.Agr. (seconded to Division of Land Research and Regional Survey).
Senior Technical Officer—C. H. Thompson, Q.D.A.

Soil Physics Section—

Senior Research Officer—G. B. Stirk, B.Sc.
Technical Officer—R. E. Prebble, B.Sc.

Soil Chemistry Section—

Senior Research Officer—A. E. Martin, B.Sc., F.R.I.C.
Senior Research Officer—R. S. Beckwith, B.Sc. (Hons.).
Senior Technical Officer—R. Reeve, Dip.Ind.Chem.
Technical Officer—Miss J. Richardson, B.Sc.
Technical Officer—I. P. Little, B.Sc.Agr.

At Canberra—

Soil Survey and Pedology Section—

Principal Research Officer—B. E. Butler, B.Sc. (Agric.).
Senior Research Officer—R. Brewer, B.Sc. (Hons.).
Senior Research Officer—J. R. Sleeman, B.Agr.Sc.
Research Officer—D. C. van Dijk, Dr.Ing.Agr., Dr.rer.nat.
Research Officer—P. H. Walker, B.Sc.Agr. (Hons.).
Research Officer—H. M. Churchward, B.Sc.Agr. (Hons.) (at Deniliquin).
Research Officer—J. A. Beattie, B.Sc.Agr. (Hons.) (at Griffith).
Technical Officer—Miss M. P. Green, B.Sc.

Soil Chemistry Section—

Research Fellow—A. Wild, B.Sc., Ph.D.
Technical Officer—H. J. Beatty, Dip.Ind.Chem.

Soil Physics Section—

Research Officer—D. S. McIntyre, M.Sc. (on study leave).
Technical Officer—A. V. Blackmore, B.Sc. (on study leave).

At Hobart—

Soil Survey and Pedology Section—

Principal Research Officer—K. D. Nicolls, B.Agr.Sc., B.Sc.
Research Officer—G. M. Dimmock, B.Sc.
Research Officer—J. Loveday, M.Ag.Sc. (on study leave).

Soil Chemistry Section—

Technical Officer—A. M. Graley, B.Sc.
Technical Officer—J. L. Honeysett, B.Sc.

At Perth—

Soil Survey and Pedology Section—

Senior Research Officer—M. J. Mulcahy, B.Sc. (Forestry).
Research Officer—W. M. McArthur, B.Sc. (Hons.).
Technical Officer—E. Bettenay, B.Sc. (Agric.).

Soil Chemistry Section—

Principal Technical Officer—A. G. Turton, B.Sc.
Technical Officer—F. J. Hingston, B.Sc.

35. Division of Tribophysics.

(Head-quarters: University of Melbourne.)

Chief—W. Boas, D.Ing., M.Sc., F.A.A.
Principal Research Officer—L. M. Clarebrough, Ph.D., B.Met.E., M.Eng.Sc.
Principal Research Officer—M. E. Hargreaves, Ph.D., B.Met.E.
Principal Research Officer—J. K. Mackenzie, Ph.D., B.A. (Hons.), B.Sc.
Principal Research Officer—M. F. R. Mulcahy, D.Phil., M.Sc., A.G.Inst.Tech.
Senior Research Officer—A. J. Davis, B.Eng.
Senior Research Officer—D. Michell, B.E.E.
Senior Research Officer—A. J. W. Moore, Ph.D., B.Sc.
Senior Research Officer—J. F. Nicholas, B.A. (Hons.), B.Sc.
Senior Research Officer—G. J. Ogilvie, Ph.D., B.Met.E., M.Eng.Sc.
Senior Research Officer—J. V. Sanders, Ph.D., B.Sc. (Hons.).
Senior Research Officer—Mrs. H. M. C. Sosnowsky, Ph.D.
Senior Research Officer—G. W. West, B.E.E., B.Sc.
Research Officer—B. D. Cuming, Ph.D., M.Sc.
Research Officer—E. Gillam, B.Sc. (Hons.), M.S. (Calif.).
Research Officer—E. A. Faulkner, M.A. (Hons.).
Research Officer—D. F. Klemperer, Ph.D., B.Sc.
Research Officer—K. Schröder, Dr.rer.nat.
Research Officer—J. A. Spink, M.Sc.
Senior Technical Officer—G. Brinson, B.Sc.
Technical Officer—E. D. Hondros, B.Sc.
Technical Officer—M. H. Loretto, B.Met. (Hons.).
Technical Officer—E. Lovegrove, A.R.M.T.C.
Technical Officer—G. R. Perger, F.R.M.T.C.
Technical Officer—R. G. Sherwood, A.R.M.T.C.
Technical Officer—A. J. White, A.R.M.T.C.

36. Wildlife Survey Section.

(Head-quarters: Canberra, Australian Capital Territory.)

Officer-in-charge—F. N. Ratcliffe, O.B.E., B.A. (Hons.).
Senior Principal Research Officer—R. Carrick, B.Sc. (Hons.), Ph.D.
Sectional Secretary—F. N. Robinson, B.A. (Hons.).
Senior Research Officer—A. L. Dyce, B.Sc.Agr. (Hons.).
Senior Research Officer—H. J. Frith, B.Sc.Agr.
Senior Research Officer—M. E. Griffiths, M.Sc.
Research Officer—J. H. Calaby, A.S.M.B.
Research Officer—G. W. Douglas, B.Agr.Sc. (seconded to Victorian Lands Department).
Research Officer—G. M. Dunnet, B.Sc. (Hons), Ph.D.
Research Officer—B. J. G. Marlow, B.Sc. (Hons.).
Research Officer—R. Mykytowycz, B.V.M., D.V.M.
Senior Technical Officer—I. C. R. Rowley, B.Agr.Sc.
Technical Officer—S. J. J. F. Davies, B.A. (Hons.).
Technical Officer (Librarian)—Mrs. N. Keith, B.Sc.
Technical Officer—C. F. Fysh, B.Sc.

At Perth, Western Australia—

Principal Research Officer—D. L. Serventy, B.Sc. (Hons.), Ph.D.

At Woodstock, Western Australia—

Research Officer—E. H. M. Ealey, M.Sc.

At Albury, New South Wales—

Senior Research Officer—K. Myers, B.Sc. (Hons.).
Research Officer—W. E. Poole, B.Sc. (Hons.).

At Armidale, New South Wales—

Senior Research Officer—B. V. Fennessy, B.Agr.Sc.
Senior Technical Officer—E. J. Waterhouse, B.Ag.Sc.

37. Wool Textile Research Laboratories.

Senior Officer-in-charge—F. G. Lennox, D.Sc.

At Wool Textile Research Laboratory, Melbourne—

Biochemistry Unit, 343 Royal-parade, Parkville, Victoria—

Officer-in-charge—F. G. Lennox, D.Sc.
Laboratory Secretary—C. Garrow, B.Com., D.P.A., A.A.S.A.
Principal Research Officer—W. G. Crewther, M.Sc.
Principal Research Officer—R. D. B. Fraser, B.Sc. (Hons.), Ph.D.
Principal Research Officer—M. A. Jermyn, M.Sc., Ph.D.
Principal Research Officer—S. J. Leach, B.Sc.Tech., Ph.D. (abroad).
Principal Research Officer—H. Lindley, B.A., Ph.D.
Principal Research Officer—J. M. Swan, B.Sc., Ph.D., D.I.C.
Senior Research Officer—J. M. Gillespie, M.Sc.
Senior Research Officer—B. S. Harrap, M.Sc., Ph.D.

Senior Research Officer—I. J. O'Donnell, M.Sc.
Senior Research Officer—T. A. Pressley, B.Sc.
Senior Research Officer—W. E. Savige, M.Sc., Ph.D.
Senior Research Officer—D. H. Simmonds, M.Sc., Ph.D.
Senior Research Officer—E. O. P. Thompson, M.Sc., Dip.Ed., Ph.D.
Senior Research Officer—E. F. Woods, M.Sc., A.R.M.T.C.
Research Officer—J. A. Maclaren, M.Sc., Ph.D.
Research Officer—T. P. MacRae, M.Sc.
Research Officer—G. E. Rogers, M.Sc.
Research Officer—C. M. Roxburgh, Ph.D., B.Sc.
Research Officer—P. H. Springell, Ph.D., M.A.
Research Officer—G. Youatt, B.Sc. (Hons.), Ph.D.
Principal Technical Officer—J. P. E. Human, M.Sc., Ph.D.
Senior Technical Officer—A. B. McQuade, B.Sc.
Senior Technical Officer—R. J. Rowlands, B.Sc.
Senior Technical Officer—K. I. Wood, A.R.M.T.C.
Technical Officer—L. M. Dowling, B.Sc.
Technical Officer—I. W. Stapleton, Dip.Chem.

At Wool Textile Research Laboratory, Sydney—

Physics and Engineering Unit, The Hermitage, 338 *Blaxland-road, Ryde, New South Wales—*

Officer-in-charge—V. D. Burgmann, B.Sc., B.E.
Technical Secretary—H. W. M. Lunney, B.Sc., B.E.
Principal Research Officer—J. G. Downes, B.Sc.
Principal Research Officer—N. F. Roberts, M.Sc.
Senior Research Officer—M. Feughelman, B.Sc. (Hons.), M.Sc., A.S.T.C.
Senior Research Officer—H. W. Holdaway, B.Sc. (Hons.), B.E.
Senior Research Officer—Mrs. K. R. Makinson, B.A. (Hons.).
Research Officer—M. W. Andrews, B.Sc. (Hons.) (abroad).
Research Officer—K. Baird, M.Sc. (abroad).
Research Officer—E. G. Bendit, B.Sc. (Eng.), M.Sc.
Research Officer—J. F. P. James, M.Sc. (abroad).
Research Officer—Miss V. Laws, M.Sc.
Research Officer—D. T. Liddy, B.Sc. (Hons.).
Research Officer—P. Nordon, B.Sc., A.S.T.C. (abroad).
Research Officer—I. M. Stuart, M.Sc.
Research Officer—I. C. Watt, M.Sc., Ph.D.
Senior Technical Officer—A. R. Haly, B.Sc.
Senior Technical Officer—B. G. Leary, A.S.T.C.
Technical Officer—J. E. Algie, A.S.T.C.
Technical Officer—Miss J. C. Griffith, M.Sc., A.S.T.C.
Technical Officer—R. H. Kennett, A.S.T.C.
Technical Officer—B. H. Mackay, A.S.T.C.
Technical Officer—G. B. McMahon, B.Sc. (Hons.).
Technical Officer—B. J. Rigby, A.S.T.C. (abroad).
Technical Officer—G. L. Stott, A.S.T.C.
Technical Officer—A. G. Stutter, B.Sc. (Hons.).
Librarian—Mrs. J. S. Thwaite, B.A.

At Wool Textile Research Laboratory, Geelong, Victoria—

Officer-in-charge—M. Lipson, B.Sc., Ph.D.
Technical Secretary—T. Topham, A.M.I.I.A., A.T.I.
Senior Research Officer—A. J. Farnworth, M.Sc., Ph.D., A.G.Tech.Inst.
Senior Research Officer—G. W. Walls, B.Sc.
Senior Research Officer—G. F. Wood, B.Sc. (Hons.), Ph.D.
Research Officer—C. A. Anderson, B.Sc.
Research Officer—J. H. Bradbury, M.Sc., Ph.D.
Research Officer—J. Delmenico, B.Sc. (Hons.).
Research Officer—J. R. McPhee, B.Sc., Ph.D.
Research Officer—D. S. Taylor, B.A., B.Sc., Ph.D.
Senior Technical Officer—B. O. Lavery.
Senior Technical Officer—A R. W. Lee, B.Sc., A.Mus.A., Dip.Ed.
Technical Officer—M. A. Higgins, A.G.Inst.Tech.
Technical Officer—G. C. West, A.G.Inst.Tech.

XXXIV. PUBLISHED PAPERS.

The following papers have been published during the year. Letters Patent received by the Organization during the year are also included.

1. ANIMAL GENETICS SECTION.

Barker, J. S. F., *and* Barker, C. I. (1956).—The mutagenic action of formaldehyde on *Drosophila melanogaster. Aust. J. Biol. Sci.* 9 : 382-99.

Dowling, D. F. (1956).—An experimental study of heat tolerance of cattle. *Aust. J. Agric. Res.* 7 : 469-81.

Nay, T. (1956).—Mast cells and hair growth in the mouse. *Aust. J. Biol. Sci.* 9 : 442-7.

Nay, T., *and* Hayman, R. H. (1956).—Sweat glands in Zebu (*Bos indicus* L.) and European (*B. taurus* L.) cattle. I. Size of individual glands, the denseness of their population, and their depth below the skin surface. *Aust. J. Agric. Res.* 7 : 482-94.

Rendel, J. M. (1957).—Relationship between coincidence and crossing over in *Drosophila. J. Genet.* 55: 95-9.

Rendel, J. M., *and* Sheldon, B. L. (1956).—The effect of cold treatment on mutation in *Drosophila melanogaster. Aust. J. Agric. Res.* 7 : 566-73.

Sheldon, B. L. (1956).—Genetic parameters associated with characters affecting egg production in the domestic fowl. I. The heritability of total egg production during the pullet year. *Aust. J. Agric. Res.* 7 : 625-9.

Sobey, W. R., *and* Turnbull, K. E. (1956).—Fertility in rabbits recovering from myxomatosis. *Aust. J. Biol. Sci.* 9 : 455-61.

2. DIVISION OF ANIMAL HEALTH AND PRODUCTION.

Alexander, G. (1956).—Changes in weight of lambs during the first thirty-six hours of life. *Aust. Vet. J.* 32: 321-4.

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XXXV. FINANCE.

1. Expenditure.

The statement of expenditure from 1st July, 1956, to 30th June, 1957, is as follows:—

	£	£	£
(*a*) Salaries and contingencies			293,638*
(*b*) Investigations—			
(i) Animal Health and Production Problems		654,502	
Less contributions from—			
Wool Research Trust Account	297,505		
Australian Dairy Produce Board	1,953		
Australian Meat Board	425		
Ian McMaster Bequest	5,000		
Alex. Fraser Memorial Fund	173		
Wm. McIlrath Fellowship	2,250		
Commonwealth Bank	213		
Burdekin Bequest (Drought feeding)	1,106		
Special Revenue Funds—			
"Belmont" Field Station	137		
		308,762	
			345,740
(ii) Biochemistry and General Nutrition Problems		114,628	
Less contributions from—			
Wool Research Trust Account	39,143		
		39,143	
			75,485
(iii) Plant Problems—Division of Plant Industry		683,030	
Less contributions from—			
Wool Research Trust Account	124,361		
		124,361	
			558,669
(iv) Entomology Problems			195,362
(v) Soils and Irrigation Problems of Irrigation Settlements—			
(*a*) Citricultural—Research Station, Griffith		52,639	
Less contributions from—			
N.S.W. Water Conservation and Irrigation Commission	2,000		
Special Revenue Fund—Griffith Research Station	3,902		
		5,902	
			46,737
(*b*) Viticultural—Research Station, Merbein		69,230	
Less contributions from—			
Dried Fruits Control Board	1,479		
Mildura Co-op. Fruit Company	250		
Irymple Packing Company	250		
Red Cliffs Co-op. Fruit Company	250		
Aurora Packing Company	250		
Co-op. Dried Fruit Sales Ltd.	250		
		2,729	
			66,501
			113,238
(vi) Soil Problems			210,788
(vii) Food Preservation and Transport Problems		226,905	
Less contributions from—			
N.S.W. Department of Agriculture	1,774		
Metropolitan Meat Industry Board	500		
Queensland Meat Industry Board	1,275		
Australian Meat Board	381		
Australian Egg Board	750		
Commonwealth Can Makers' Association	875		
Department of Primary Industry	3,252		
Department of Trade	8,084		
Various Contributors	900		
Department of Scientific and Industrial Research (U.K.)	886		
		18,677	
			208,228
(viii) Forest Products Problems		308,998	
Less contributions from—			
Australian Paper Manufactures Ltd. Associated Pulp and Paper Mills Ltd. Australian Newsprint Mills New Zealand Forest Products Ltd.	2,832		
Department of Territories	3,251		
General Donations	2,792		
Pole Strength Research Account	8,533		
Australian Plywood Board	7,499		
		24,907	
			284,091
(ix) Mining and Metallurgy		42,426	
Less contributions from—			
Australasian Institute of Mining and Metallurgy	703		
State Electricity Commission	316		
General Donations	192		
Territory Enterprises Pty. Ltd.	2,046		
		3,257	
			39,169
(x) Radio Research		43,635	
Less contributions from—			
Postmaster-General's Department	10,909		
		10,909	
			32,726

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* The main items of expenditure under this heading are salaries of the Administrative Staff at the Organization's Head Office; salaries and expenses of officers at the Liaison Offices in London and Washington; staff and upkeep of State Committees; travelling expenses of Head Office Staff; and general office expenditure.

	£	£	£
(xi) Research Services		260,581	
Less contributions from—			
Wool Research Trust Account	7,702		
		7,702	
			252,879
(xii) Industrial Chemistry		539,148	
Less contributions from—			
Cement and Concrete Association of Australia	937		
Mt. Morgan Ltd., Mt. Lyell Mining and Railway Co. Ltd., Mt. Isa and Peko N.L.	9,542		
Consolidated Zinc Pty. Ltd	1,187		
Various Contributors	2,061		
		13,727	
			525,421
(xiii) Fisheries Investigations		172,000	
Less contributions from—			
N.S.W. Government	80		
Department of the Navy	3,757		
Department of Primary Industry	2,340		
Drug Houses of Australia	25		
		6,202	
			165,798
(xiv) Mathematical Statistics			55,989
(xv) National Standards Laboratory			526,637
(xvi) Tribophysics			87,762
(xvii) Building Research		137,905	
Less contributions from—			
Associated Fibrous Plaster Manufactures of Australia	1,115		
Paint Manufacturers' Association	1,193		
		2,308	
			135,597
(xviii) Plant Fibre Research			36,565
(xix) Radiophysics Research		333,552	
Less contributions from—			
Snowy Mountains Hydro-electric Authority	14,420		
		14,420	
			319,132
(xx) Metallurgical Research			9,020
(xxi) Tobacco Research		22,770	
Less contribution from Tobacco Research Trust	22,770		
		22,770	
(xxii) Meteorological Physics			74,592
(xxiii) Dairy Research			60,101
(xxiv) Wool Textile Research		346,634	
Less contributions from—			
Wool Research Trust Account	335,654		
Department of Supply	1,000		
Princeton Institute, U.S.A.	255		
		336,909	
			9,725
(xxv) Fuel Research			153,776
(xxvi) Wildlife Survey		107,186	
Less contribution from—			
Wool Research Trust Account	55,101		
		55,101	
			52,085
(xxvii) Land Research and Regional Survey		135,744	
Less contributions from—			
Department of National Development	20,060		
Department of Territories	16,634		
Australian Meat Board	515		
		37,209	
			98,535
(xxviii) Genetics Investigations		53,388	
Less contribution from—			
Wool Research Trust Account	27,194		
		27,194	
			26,194
(xxix) Miscellaneous—			
(*a*) Biophysical Research		2,236	
(*b*) Tracer Elements Investigations		885	
(*c*) Extra-mural Investigations		21,888	
(*d*) Furlough and Compensation		15,970	
(*e*) Various		18,365	
		59,344	
Less contributions from—			
Science and Industry Endowment Fund	513		
Western Australian Golf Association	1		
Australian Hide and Leather Industries Board	2,087		
Australian Dairy Produce Board	3,716		
Department of Defence Production	1,502		
Northern Territory Administration	1,982		
N.S.W. State Cancer Council	916		
George Aitken Pastoral Research Trust	23		
Broken Hill Associated Smelters Pty. Ltd	83		
Commonwealth Bank	2,368		
General Donations	412		
		13,603	
			45,741
(xxx) Unforeseen and Urgent			1,000
Total of Item (*b*)—Investigations			4,700,045

	£	£	£
(*c*) Grants—			
(i) Research Associations—			
Leather Research Association	7,500		
Bread Research Institute	10,000		
Wine Research Institute	3,500		
Tobacco Research Trust	10,500		
Coal Association (Research) Ltd.	10,000		
		41,500	
(ii) Overseas Research Studentships		51,412	
		92,912	
Less contributions from—			
Wool Research Trust Account	3,904		
Science and Industry Endowment Fund	1,346		
		5,250	
			87,662
Total Salaries and Contingencies, Investigations, and Grants			5,081,345
Less receipts from sales of equipment, publications, &c., and revenue earned by Divisions and Sections, details of which are shown in Section 5			122,621
			4,958,724

2. CONTRIBUTIONS AND DONATIONS.

The following statement shows the receipts and disbursements during the year 1956-57 of the funds provided by outside bodies and recorded in the special account entitled "The Specific Research Fund".

	Receipts 1956-57 and balances brought forward from 1955-56. £		Expenditure 1956-57. £
Wool Industry Fund (Details are shown in Section 4)	585,645		
Less Amount transferred to Wool Research Trust Account	318,611		
	267,034	..	220,900
Commonwealth Bank (Animal Health and Production, and Genetics, Investigations)	275	..	213
Australian Wool Board (Biochemistry and General Nutrition Investigations—Sheep Research)	789	..	..
Australian Dairy Produce Board (Mastitis Investigations)	1,740	..	1,740
W. McIlrath Research Fellowship Fund (Expenses of Fellowship—Animal Husbandry)	2,250	..	2,250
Australian Meat Board (Parasitological Studies of Cattle)	431	..	425
Australian Dairy Produce Board (Parasitological Studies of Cattle)	216	..	213
Alexander Fraser Memorial Fund (Animal Health and Production Investigations)	300	..	173
N.S.W. State Cancer Council (Animal Health and Production—Cancer Research Project)	1,084	..	916
Estate of the late Captain Ian McMaster (Animal Health and Production Investigations)	5,143	..	5,000
Commonwealth Bank (Plant Breeding Investigations—Plant Industry)	3,000	..	2,367
General Donations (Plant Industry)	50	..	..
Western Australian Golf Association (Plant Industry Investigations)	51	..	1
United Graziers' Association of Queensland—Buffalo Fly and Cattle Tick Investigations (Entomology)	172	..	..
Australian Hide and Leather Industries Board (Cattle Tick and Leather Investigations)	4,174	..	2,087
General Donations (Division of Entomology)	32	..	..
Burdekin Bequest (Drought Feeding Investigations)	1,800	..	1,106
Department of Supply (Soil Mechanics Investigations)	16,500	..	..
N.S.W. Water Conservation and Irrigation Commission (Maintenance of Research Station)	2,000	..	2,000
Mildura Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	250	..	250
Ilrymple Packing Co. (Dried Vine Fruits Investigations, Merbein)	250	..	250
Red Cliffs Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	250	..	250
Aurora Packing Company (Dried Vine Fruits Investigations, Merbein)	250	..	250
Co-op. Dried Fruit Sales Ltd. (Dried Vine Fruits Investigations, Merbein)	250	..	250
Dried Fruits Control Board (Dried Fruits Investigations)	1,600	..	1,479
Nyah-Woorinen Dried Fruits Inquiry Committee (Dried Fruits Investigations)	375	..	..
Australian Meat Board (Meat Investigations)	500	..	381
Metropolitan Meat Industry Board of New South Wales (Meat Investigations)	500	..	500
Queensland Meat Industry Board (Meat Investigations)	1,275	..	1,275
Department of Trade (Mutton Dehydration Investigations)	8,509	..	8,075A
N.S.W. Department of Agriculture (Food Investigations)	1,000	..	901
Department of Primary Industry (Fruit Fly Investigations—Food Investigations)	3,252	..	3,252
Apple and Pear Board (Food Investigations)	500	..	..
Various Contributors (Division of Food Preservation and Transport)	4,493	..	900
Australian Egg Board (Division of Food Preservation and Transport—Egg Investigations)	750	..	750
Commonwealth Can Makers' Association (Division of Food Preservation and Transport—Tinplate Investigations)	875	..	875
Department of Scientific and Industrial Research (U.K.)—Co-operative Meat Investigations (Food Preservation and Transport)	1,128	..	886
N.S.W. Department of Agriculture—Quick Freezing of Fruit and Vegetables (Division of Food Preservation and Transport)	938	..	873
Paper Companies and New Zealand Forest Products (Paper Pulp Investigations)	3,500	..	2,832
Sundry Contributors (Forest Products Investigations)	8,947	..	2,793
General Donations—Pole Strength Research (Forest Products)	16,880	..	8,533
Department of Territories (Development of Pulp and Paper Industry in New Guinea)	3,267	..	3,251
Australian Plywood Board—Veneer, Gluing, and Plywood Research (Forest Products)	8,000	..	7,499
Australasian Institute of Mining and Metallurgy (Mineragraphic Investigations)	1,000	..	703
Territory Enterprises Pty. Ltd.—Tests on Base Metal Ore (Ore-dressing Investigations)	2,485	..	2,046

A.—Includes adjustment of £9 which relates to 1955-56 expenditure.

	Receipts 1956-57 and balances brought forward from 1955-56.	Expenditure 1956-57.
	£	£
Postmaster-General's Department (Radio Research)	11,000	10,909
Drug Houses of Australia (Division of Fisheries—Agar Production)	25	25
Miscellaneous Contributors (Division of Industrial Chemistry)	5,147	2,061
Department of Supply (Textile Degradation Investigations)	1,000	1,000
Mt. Morgan Ltd., Mt. Lyell Mining and Railway Co. Ltd., Mt. Isa Ltd., and Peko N.L. (Industrial Chemistry—Co-operative Investigations)	4,725	4,725
Mt. Morgan Ltd., Mt. Lyell Mining and Railway Co. Ltd., Mt. Isa Ltd., and Peko N.L.—Electrowinning of Copper (Industrial Chemistry)	4,991	4,817
N.S.W. Government (Fisheries Investigations)	250	80
General Donations (Ore-dressing Investigations)	3,065	192
State Electricity Commission of Victoria—(Mineragraphic Investigations—Geological Consultations)	1,410	316
Broken Hill Associated Smelters Pty. Ltd.—Co-operative Research (Tribophysics)	83	83
Department of the Navy (Marine Fouling Investigations—Division of Fisheries)	4,138	3,757
Cement and Concrete Association of Australia (Cement Investigations—Industrial Chemistry)	1,500	937
Department of Defence Production—Examination of Gauges (Metrology)	1,509	1,502
General Donations (Division of Physics)	1,000	412
Committee for Dried Fruit Marketing (Division of Meteorological Physics)	12	..
Sundry Contributors (Commonwealth Scientific and Industrial Research Organization—Publications)	24	..
Science and Industry Endowment Fund	2,022	1,859
Miscellaneous Contributors (Mathematical Instruments Section)	126	..
Miscellaneous Contributors (Mineragraphic Investigations)	103	..
Wool Scourers, Carbonizers, and Fellmongers Federation of Australia (Wool Textile Research)	3,000	..
Associated Fibrous Plaster Manufactures of Australia—Fibrous Plaster Research (Division of Building Research)	1,250	1,115
Paint Manufacturers' Association—Paint Research on Plaster Surfaces (Division of Building Research)	1,193	1,193
General Donations (Division of Building Research)	1,225	..
Consolidated Zinc Pty. Ltd.—Resin-in-pulp Project (Industrial Chemistry)	1,600	1,187
Smith, Kline, and French Laboratories, U.S.A.—Alkaloids Research (Industrial Chemistry)	1,000	..
Department of Primary Industry—Pearl Shell Survey (Division of Fisheries)	2,340	2,340
Shell (Chemical) Aust. Pty. Ltd.—Moth-proofing Investigations (Wool Textile Research)	500	..
Patons and Baldwins Ltd.—Solvent Degreasing (Wool Textile Research)	1,250	..
Department of National Development—Kimberley Research Station	1,557	1,397
Australian Dairy Produce Board—(Farm Mechanization Research)	500	500
Snowy Mountains Hydro-electric Authority—(Cloud Seeding Investigations—Division of Radiophysics)	17,850	14,420
Australian Dairy Produce Board—(Cheese Making Project—Dairy Research)	5,810	3,163B
Department of Territories (Resources Survey—Papua and New Guinea)	17,675	16,634
Department of National Development (Northern Australia Regional Survey)	18,663	18,663
Australian Meat Board—Pasture Development in Central Australia (Land Research and Regional Survey)	733	515
Associated Woollen Worsted Textile Manufacturers of Australia (Wool Textile Research)	2,032	..
Various Contributors (International Wool Textile Research Conference)	50	..
General Donations (Wool Textile Research)	11	..
Princeton Institute, U.S.A.—Princeton Wool Project (Wool Textile Research)	255	255
General Donations (Coal Investigations)	201	..
N.T. Administration—Goose Damage to Rice Crops (Wild Life Investigations)	2,758	1,982
George Aitken Pastoral Research Trust (Wildlife Survey Section)	23	23
Special Revenue Fund—"Belmont" Field Station, Rockhampton (Animal Health and Production Investigations)	2,032	137
Special Reserve Fund—National Field Station, "Gilruth Plains", Cunnamulla (Animal Health and Production Investigations)	9,792	..
Special Revenue Fund—Research Station, Mareeba (Tobacco Research Investigations)	26	..
Special Revenue Fund—Grazing Trials, Samford Farm (Plant Industry Investigations)	432	..
Special Revenue Fund—Burdekin Bequest (Animal Health and Production Investigations)	1,751	..
Special Revenue Fund—Research Station, Griffith (Citricultural Investigations)	18,054	3,902
Australian Tobacco Research Trust (Tobacco Investigations)	76,000	50,388
Suspense Account	Cr. 6,808C	..
	602,950	438,934

B.—Includes adjustment of £53 which relates to 1955-56 expenditure.

C.—Adjustment will be effected in the appropriate contributors' account during 1957-58.

3. Wool Research Trust Account.

Complete details of transactions during 1956-57 are as follows:—

	£	£	£
Balance in Account, July 1, 1956			..
Receipts 1956-57.			
Department of Primary Industry	..	533,299	
Revenue—			
Animal Health and Production—			
Cobram Field Station	791		
Regional Pastoral Laboratory, Armidale	25,520		
Sheep Biology Laboratory, Prospect	2,664		
McMaster Field Station	2,574		
McMaster Laboratory	1,906		
National Field Station—"Gilruth Plains"	12,254		
Tooradin Field Station	1,274		
Plant Industry—			
"Glen Lossie" Field Station, Kojonup	12,755		
Falkiner Memorial Field Station, Deniliquin	9,772		
Mitchell Laboratory, Trangie	187		
Biochemistry and General Nutrition—			
Glenthorne Field Station	6,586		
Robe Field Station	162		

	£	£	£
Wool Textile Research Laboratories—			
Textile Laboratory, Geelong	6,983		
Biochemistry Laboratory, Melbourne	67		
Textile Laboratory, Sydney	8		
Wildlife—Wildlife Investigations	407		
Industrial Chemistry—Fishermen's Bend Laboratory	10		
		83,920	
Amount transferred from Wool Industry Fund	..	318,611	
Total Receipts 1956-57	..	..	935,830
			935,830
Expenditure 1956-57.			
Division of Animal Health and Production—			
Parkville—			
Sheep Physiology Investigations—			
Tooradin	6,399		
Frodsley	2,938		
		9,337	
McMaster Laboratory—			
Parasitology Investigations—New South Wales	16,685		
Dipping and External Parasites	3,443		
Hollerith Equipment	3,200		
Nematode Ecology	2,604		
Fluke Investigations	2,349		
		28,281	
Sheep Biology Laboratory, Prospect—			
Administrative and General Expenses	86,995		
Fleece Analysis	7,488		
Wool Biology	60,653		
Strain Trial	7,376		
		162,512	
Regional Pastoral Laboratory, Armidale	..	64,582	
National Field Station, "Gilruth Plains"—Animal Breeding and Strain Trial Investigations	..	31,113	
McMaster Field Station—			
Wool Production and Sheep Breeding	..	1,680	
			297,505
Division of Plant Industry—			
Agrostology Investigations	120,216		
Flood Damage, Deniliquin	4,145		
			124,361
Research Services—			
Agricultural Research and Extension Liaison	7,593		
Wool Publications	109		
			7,702
Division of Industrial Chemistry—			
Expenditure on Wool Textile Research—			
Chemical Physics Investigations	14,593		
Organic Chemistry Investigations	12,664		
Physical Chemistry Investigations	4,360		
			31,617
Division of Biochemistry and General Nutrition—			
Biochemical and Nutritional Investigations	..	..	39,143
Wool Textile Research Laboratories—			
Wool Textile Research	..	..	304,037
Wildlife Survey Section—			
Wildlife Survey	..	..	55,101
Animal Genetics Section—			
Animal Genetics Investigations	..	..	27,194
Miscellaneous—			
Overseas Studentships	..	..	3,904
Total C.S.I.R.O. Investigations	..	..	890,564
Grants from Wool Research Trust Account to institutions undertaking research in agricultural economics relating to wool production—			
Department of Primary Industry—			
Bureau of Agricultural Economics	40,847		
Wool Adviser	4,419		
Total Department of Primary Industry Expenditure	..	..	45,266
Total Expenditure 1956-57	..	..	935,830
Balance carried forward to 1957-58	..	..	Nil

4. WOOL INDUSTRY FUND.

A credit balance of £24,801 was brought forward from 1955-56 in the Wool Industry Fund Account. A further £560,844 was received during 1956-57. Of this amount £318,611 was transferred to the Wool Research Trust Account to meet the deficiency in that account (*see* Section 3). Expenditure during 1956-57 amounting to £220,900 was incurred as follows:—

	£	£	£	£
Expenditure by C.S.I.R.O. Divisions and Sections.				
Biological Research—				
Animal Health and Production—				
Sheep Biology Laboratory, Prospect—				
Equipment	19,226			
Development expenditure—Water and soil conservation	880			
		20,106		
Regional Pastoral Laboratory and "Chiswick" Field Station, Armidale—Construction of small buildings and roads and provision of services	7,127			
		7,127		
Cobram Field Station—Equipment	1,088			
		1,088		
McMaster Laboratory—Developmental expenditure on Parasitology block at McMaster Field Station	1,172			
		1,172		
National Field Station, "Gilruth Plains"—Equipment	683			
		683		
Regional Pastoral Laboratory, Deniliquin—Developmental expenditure	1,901			
		1,901		
			32,077	
Biochemistry and General Nutrition—				
Glenthorne Experimental Station—Fences, water reticulation, &c.	..	761		
			761	
Plant Industry—				
"Glen Lossie" Field Station, Kojonup, Western Australia—				
Developmental expenditure—Clearing, fencing, water supply, &c.	..	3,039		
Canberra Laboratory—Glass-house	..	2,436		
Dickson Experimental Station, Canberra—Fencing and irrigation	..	853		
			6,328	
Wildlife Survey—				
Myxomatosis and Rabbit Investigations, Albury—Fencing	..	952		
			952	
Wool Textile Research—				
Biochemistry Laboratory, Melbourne—				
Plant	170			
Equipment	6,403			
		6,573		
Textile Laboratory, Geelong—				
Buildings and site	3,027			
Textile machinery	12,883			
Plant	11,337			
		27,247		
Physics and Engineering Unit, Sydney—				
Plant	6,240			
Modifications to laboratory	6,335			
		12,575		
			46,395	
				86,513

	£	£	£	£
Expenditure by Department of Works on C.S.I.R.O. Buildings.				
Biological Research—				
Animal Health and Production—				
Sheep Biology Laboratory, Prospect—				
Animal House No. 1 ..	23,130			
Main Laboratory ..	7,525			
Climate controlled building	238			
Reconstruction of driveway	1,512			
Manure pit	3,895			
Electricity sub-station ..	538			
Sewerage	838			
		37,676		
			37,676	
Biochemistry and General Nutrition—				
Glenthorne Experimental Station—				
Fodder Processing Building ..	650			
		650		
			650	
Animal Genetics—				
Extensions to Zoology Building, University of Sydney ..	480			
		480		
			480	
Minor Works—				
New South Wales	705			
Victoria	1,121			
Australian Capital Territory ..	12			
		1,838		
			1,838	
Wool Textile Research—				
Wool Textile Research Laboratories—				
Biochemistry Laboratory, Melbourne—				
Laboratory building ..	1,012			
Extension to chemical store	1,060			
		2,072		
Textile Laboratory, Geelong—				
Insulation and flooring of machinery	1,444			
Fire alarm system ..	3,630			
		5,074		
Textile Laboratory, Sydney—				
Laboratory building ..	9,952			
		9,952		
			16,098	
Minor Works—				
New South Wales	1,199			
Victoria	6,138			
		7,337		
			7,337	
				64,079
Grants from Wool Industry Fund for Extra-mural Co-operative Wool Research.				
Biological Projects—				
Victoria—				
Melbourne University—				
Electrolyte physiology studies	6,000			
Department of Lands and Survey—				
Rabbit Investigations ..	5,000			
		11,000		
Western Australia—				
Institute of Agriculture—				
Ruminal flora studies ..	5,200			
Department of Agriculture—				
Clover fertility	1,300			
		6,500		
South Australia—				
Roseworthy Agricultural College—				
Progeny testing	4,185			
Waite Institute—				
Agronomy and entomology	8,601			
University of Adelaide—				
Animal ecology	2,035			
Department of Agriculture—				
Ovine brucellosis and fleece measurement	3,200			
		18,021		
Australian Capital Territory—				
Australian National University—				
Myxomatosis investigations	3,150			
		3,150		
Queensland—				
Department of Agriculture and Stock—				
Fertility and neo-natal mortality	2,110			
Progeny testing and wool metrology	350			
Ovine brucellosis ..	50			
Blowfly strike control ..	600			
Melioidosis	250			
University of Queensland—				
Sheep physiology ..	1,050			
Acclimatization studies ..	540			
Silage Investigations ..	1,500			
		6,450		
New South Wales—				
University of Technology—				
Wool clip analysis ..	7,500			
University of Sydney—				
Animal physiology investigations	2,500			
Controlled artificial insemination of the ewe ..	900			
Seasonal variations in ram fertility	1,200			
Department of Agriculture—				
Disordered metabolism ..	815			
Ectoparasites	400			
		13,315		
			58,436	
Wool Textile Research—				
Gordon Institute of Technology—				
Wool Textile investigations	4,118			
Wool Industries Research Association, U.K. ..	1,254			
		5,372		
			5,372	
				63,808
Special Non-recurring Project—				
Solvent Degreasing Process ..	6,500			
		6,500		
			6,500	
				6,500
				220,900

5. MISCELLANEOUS RECEIPTS.

During 1956-57 miscellaneous receipts amounted to £122,621. Of this amount £21,220 represented proceeds of sales of equipment, publications, &c. The balance of £101,401 represented revenue earned by Divisions and Sections apart from the Special and Wool Revenue included under Sections 2 and 3 respectively. Details of the receipts are as follows:—

Revenue Receipts.

	£	£	£
Division of Animal Health and Production—			
Sale of Contagious Pleuro-pneumonia Vaccine	12,542		
Mastitis Investigations	3,470		
Parkville Laboratory	69		
Toxaemic Jaundice Investigations, Parkville, Victoria	224		
Oestrus Experiments	353		
Poultry Breeding Investigations ..	10,992		
Contagious Pleuropneumonia Investigations	1,767		
Bacteriological and Parasitological Investigations	83		
McMaster Field Station Revenue	1,482		
Veterinary Parasitology Laboratory, Yeerongpilly	87		
Veterinary Parasitology Laboratory, Amberley	124		
Cobram Field Station	220		
Division of Plant Industry—			
Plant Industry Investigations, Canberra	8,288		
Stanthorpe Field Station ..	1,319		
Plant and Soils Laboratory, Brisbane	8		
Division of Soils—			
Merbein Research Station ..	4,554		
Soils Investigations	249		
Division of Food Preservation and Transport	258		

	£	£	£
Division of Forest Products	107		
Ore-dressing Investigations	126		
Research Services—			
Film Unit	223		
Engineering Section	36		
Division of Industrial Chemistry—			
Industrial Chemistry Investigations	40,722		
Microanalysis Investigations	3,192		
Division of Fisheries	16		
Division of Metrology	7,276		
Division of Electrotechnology	725		
Division of Physics	1,743		
Division of Building Research	267		
Division of Radiophysics	216		
Meteorological Physics Section	2		
Wild Life Survey Section	41		
Land Research and Regional Survey, Katherine	19		
Coal Research Section	601		
		101,401	
Other Receipts—			
Sales of publications	3,642		
Sales of equipment, &c.	17,578		
		21,220	
			122,621

The above sum was paid to the credit of the Trust Fund Science and Industry Account during 1956-57 and consequently reduced the requirements from Treasury sources by that amount (*see* Section 1).

6. WORKS PROJECTS (UNDER CONTROL OF C.S.I.R.O.).

Expenditure on works projects financed from funds made available directly to C.S.I.R.O. is as follows:—

	£	£	£
Animal Health and Production—			
Wool Industry Fund (details shown in Section 4)		32,077	
Less contribution from— Wool Industry Fund	32,077		
		32,077	
Plant Industry—			
Wool Industry Fund (details shown in Section 4)		6,328	
Treasury Funds—			
Canberra Experiment Station, Developmental expenditure, clearing, fencing, &c.	2,336		
Samford Experiment Station— Fencing	349		
		2,685	
		9,013	
Less contribution from— Wool Industry Fund		6,328	
			2,685
Food Preservation and Transport—			
Treasury Funds—			
Hobart Laboratory, plant for processing annexe		2,115	
			2,115
National Standards Laboratory—			
Treasury Funds—			
National Standards Laboratory, alterations to Laboratory		3,127	
			3,127
Biochemistry and General Nutrition—			
Wool Industry Fund (details shown in Section 4)		761	
Less contribution from— Wool Industry Fund		761	
Meteorological Physics—			
Treasury Funds—			
Aspendale Laboratory—			
Multiple lysimeter	975		
Construction and installation of gantry	667		
Weighing equipment	108		
Development of site	48		
		1,798	
			1,798
Wildlife Survey—			
Wool Industry Fund (details shown in Section 4)		952	
Less contribution from— Wool Industry Fund		952	
Tobacco Research—			
Tobacco Research Trust—			
Tobacco Experiment Station, Mareeba—			
Acquisition of site	11,100		
Laboratory building	7,344		
Laboratory equipment	247		
Farm buildings and machinery	970		
Housing for staff	5,881		
Motor vehicles	2,076		
		27,618	
Less contribution from— Tobacco Research Trust		27,618	
Net Treasury Expenditure			9,725

7. MISCELLANEOUS SERVICES.

	£
Contribution to Commonwealth Agricultural Bureaux	38,293
Grant to Standards Association of Australia	45,500
Contribution to Chair of Aeronautics at University of Sydney (establishment and maintenance)	5,000
Grant to National Association of Testing Authorities	11,400
Australian and New Zealand Association for the Advancement of Science	2,960
National Institute of Oceanography	6,268
	109,421

XXXVI. ACKNOWLEDGMENTS.

In various sections of this Report reference has been made as in previous years to the valuable assistance afforded by many State Departments, Universities, and other organizations and individuals. The Organization desires to express its gratitude for the help given by these bodies and persons in providing laboratory accommodation and other facilities and in many other ways. The Organization also wished to acknowledge the assistance which it has received from its Committees, the members of which have placed their knowledge and experience so freely at its disposal.

I. CLUNIES ROSS, Chairman
F. W. G. WHITE
S. H. BASTOW Executive.
H. J. GOODES
A. W. COLES

17th October, 1957.

By Authority: A. J. ARTHUR, Commonwealth Government Printer, Canberra.